JOURNAL SMPTE

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Development of Motion-Picture Positive Film by Vanadous Ion

By A. A. RASCH and J. I. CRABTREE

The inorganic developer system of Roman, employing divalent vanadium ion as the active developing agent, has been further investigated. A solution prepared from vanadium pentoxide, sulfuric and hydrobromic acids, and reduced by electrolysis was found to double the speed of motion-picture positive emulsions with development times of the order of 20 sec at 60 F. Other sensitometric properties can be controlled to match those produced by conventional processing. A motion-picture film-processing machine employing the vanadium developer has been devised and tested and is described. Developer activity is maintained by continuous electrolytic regeneration of the solution, with replenishment made only to balance carry-over losses.

Early Work

Photographic developers which employ a metal ion as the active developing agent have been known for a long time. Perhaps the most well-known system is that using ferrous iron.[1] Others, using chromium,[2,3] tungsten[3] and molybdenum,[3] have been investigated to a lesser extent over the past sixty years. Some work has also been carried out with metal-ion systems in which the metal ion is tied up with a chelating agent, and a recent paper describes the use of trivalent titanium in such a system.[4] From a practical standpoint, none of the developers investigated were found to be of much interest because of their low activity, very short exhaustion life, and poor stability.

Divalent vanadium has also been known to have photographic activity as early as 1894, when A. and L. Lumière[5] described the preparation of a vanadium developer solution. However, the Lumières were more interested in the use of vanadium salts as the light-sensitive material in printing out emulsions and did not fully investigate the use of vanadium in developers. Subsequent reference to vanadium as a developing agent[6] gives very little experimental data.

Recently a French photographic chemist, Pierre Roman, initiated a new series of investigations of the metal-ion developer system.[7] He calculated that any metal-ion system having a standard reduction potential more negative than

Communication No. 1616 from the Kodak Research Laboratories, by A. A. Rasch and J. I. Crabtree, Research Laboratories, Eastman Kodak Co., Rochester 4, N.Y. The paper was presented on October 6, 1953, at the Society's Convention at New York.
(This paper was received October 2, 1953.)

Table I. Metal-Ion Systems Which Will Reduce Silver Bromide in a Silver Bromide–Bromide-Ion System.

$Ti^{4+} + e = Ti^{3+}$	$E =$ 0.03 to 0.06 v	pH = $\bar{1}$ to 3
$W^{6+} + 3e = W^{3+}$	$E =$ 0.0	pH = 0
$V^{3+} + e = V^{2+}$	$E = -0.2$	pH = 0
$Ti^{3+} + e = Ti^{2+}$	$E = -0.4$	pH = 1
$Cr^{3+} + e = Cr^{2+}$	$E = -0.4$	pH = 0
$Sn^{4+} + 2e = Sn^{2+}$	$E = -0.7$	pH = 11

+0.120 v would be capable of reducing silver bromide in a silver bromide–bromide-ion system. More accurately, he calculated that the metal-ion system would have to satisfy the equation:

$$-0.058 \log (Br^-) - E - \frac{0.058}{n} \log \frac{(ox)}{(red)} > -0.006,$$

where

(Br^-) = bromide-ion concentration,
E = standard reduction potential,
n = electron change in the reaction,
(ox) = concentration of oxidized state of metal ion, and
(red) = concentration of reduced state of metal ion.

Roman also decided to limit his investigation to systems which are not greatly affected in activity by reasonable changes in the concentration of the oxidized form of the active compound. The system should also meet the final requirement that both oxidized and reduced forms of the active agent be soluble and dissociated.

With these requirements in mind, Roman found that the systems listed in Table I were of possible interest. Tin was eliminated because of its nonselective development characteristics, and chromium for the same reason. The divalent–trivalent titanium system was too unstable for practical use, while the other titanium system was too inactive. Solubilizing the tungsten required the use of hydrofluoric acid which, for obvious reasons, was unsuitable.

The vanadium solution, however, could be readily prepared and was found to be an active developer. Vanadium pentoxide was found to be commercially available and a suitable starting material for the preparation of the developer.

By using one of several possible methods described below, the vanadium pentoxide can be dissolved in a strongly acid solution. This solution is then electrolyzed to reduce the vanadium to the divalent state. Roman found that this solution was a very active developer, giving especially good results with motion-picture positive-type emulsions. When such a solution is used for development, the divalent vanadium is oxidized to the trivalent state, and, since the reaction is reversible, the divalent vanadium can be re-formed by further electrolysis which, as will be seen, is a feature of this metal-ion system.

Subsequent to this original work by Roman, an extensive investigation of the vanadium developer system has been made in the Kodak Research Laboratories to determine the solution composition for producing optimum results on motion-picture positive-type emulsions. An experimental machine has been designed for processing with the vanadium developer which includes a means of maintaining developer activity by electrolytic regeneration.

Preparation of Vanadium Developer

Although a number of vanadium compounds are available commercially, vanadium pentoxide is by far the cheapest but it is somewhat difficult to compound in a developer, being only slightly soluble in dilute sulfuric acid

but more readily soluble in hydrobromic acid.

Roman has described a method of solution in which sulfur dioxide is bubbled through a mixture of vanadium pentoxide and hydrobromic acid. The sulfur dioxide reduces the vanadium from the pentavalent to the readily soluble tetravalent state, as illustrated by the following equation:

$$V_2O_5 + 2HBr + SO_2 = VOSO_4 + VOBr_2 + H_2O. \quad (1)$$

The resulting solution can then be electrolyzed to form the divalent vanadium.

This method was at first used for the preparation of the various solutions used in the current experiments. However, traces of sulfur dioxide left in solution eventually formed compounds which greatly increased the fogging propensity of the developer and, since removal of the last traces of sulfur dioxide proved to be quite difficult, alternative methods of dissolving the vanadium pentoxide were sought.

One method consisted in heating the pentoxide with a warm mixture of hydrobromic and sulfuric acids, so that the bromide ion reduces the vanadium to the tetravalent state, and bromine gas is liberated, as in the equation:

$$V_2O_5 + 6HBr = 2VOBr_2 + 3H_2O + Br_2. \quad (2)$$

This method was used for some time but was always considered objectionable because it was necessary to dispose of a considerable quantity of the highly corrosive and noxious bromine gas by-product.

More recently, it was found that the vanadium pentoxide dissolves quickly in a solution of oxalic acid in concentrated sulfuric acid. The vanadium is reduced to the tetravalent state while carbon dioxide is formed as a by-product.

$$V_2O_5 + H_2C_2O_4 + 2H_2SO_4 = 2VOSO_4 + 2CO_2 + 3H_2O. \quad (3)$$

This method is much more desirable, especially when preparing large batches of the developer.

Once the solution containing the tetravalent vanadium ion has been formed, the extra acid as required by the developer formula is added and the solution is diluted to volume.

To prepare the photographically active divalent vanadium ion, the solution is placed in an electrolytic cell and electrolyzed. A cell essentially similar to that described by Roman has been used for all the preparations, consisting of a noncorroding cylindrical tank made from materials such as Plexiglas or Type 316 stainless steel. A sheet-lead liner insulated from the tank constitutes the cathode, and an unglazed porcelain cup centered in the tank contains a carbon rod, such as is used in chlorine cells, which serves as the anode.

The vanadium solution serves as the catholyte while the anolyte consists of a solution of sulfuric acid equal in total acidity to that of the vanadium solution.

Direct current is supplied to the cell from a selenium rectifier or a d-c generator. Suitable provision is made to stir the solution in the cathode compartment, and the whole unit is surrounded by a cold water cooling-jacket.

The laboratory cell described has a total cathode area of 0.12 sq m, upon which a current density of 250 amp/sq m is maintained, or a total of 30 amp, at a potential of 5 to 6 v across the cell.

The reduction process is accomplished at a current efficiency of 70%, with the result that this cell can prepare the usual developer solution at a rate of about 1 liter/hr.

The vanadium ion is reduced at the cathode in two steps:

$$VO^{+++} + 2H^+ + e = V^{+++} + H_2O, \quad (4)$$

and

$$V^{+++} + e = V^{++}. \quad (5)$$

Reaction (4) will proceed to comple-

tion using only slightly more than the theoretical current consumption, the loss in current efficiency being due to the evolution of heat. However, reaction (5) never goes to completion and in reducing 85 to 90% of the trivalent vanadium to the divalent state, current efficiencies of 50% or less prevail. This severe drop in current efficiency is the result of competition between the following reaction and reaction (5) at the cathode,

$$2H^+ + 2\varepsilon = H_2. \qquad (6)$$

Normally, it would be expected that reaction (6) would be predominant, since the standard emf's of the two systems would indicate that hydrogen ion would more readily accept an electron than would trivalent vanadium ion. However, owing to the fact that the lead cathode has a very high overvoltage to the hydrogen-forming reaction, trivalent vanadium will be more readily reduced. When about 70% of the vanadium has been reduced to the divalent state, hydrogen gas begins to form at the cathode, and the rate of formation increases quite rapidly as electrolysis proceeds. It has been found impractical to carry the electrolysis beyond the point where 85% of the vanadium has been reduced, since current efficiency at this point is extremely low. From a photographic standpoint, further electrolysis would be unnecessary since the developing capacity of the solution at this point is ample.

During the early stages of the electrolysis, oxygen forms at the anode,

$$2H_2O = O_2 + 4H^+ + 4\varepsilon, \qquad (7)$$

but, as electrolysis proceeds, a certain amount of bromide ion diffuses through the porous cup from the cathode compartment and is immediately oxidized to bromine.

$$2Br^- = Br_2 + 2\varepsilon. \qquad (8)$$

The amount of diffusion of bromide ion that occurs during the preparation of small batches of solution does not significantly change the composition of the developer. In the case of a long-term electrolysis, proper balancing of the concentrations of the starting components can be made to balance the effect of the electrolysis.

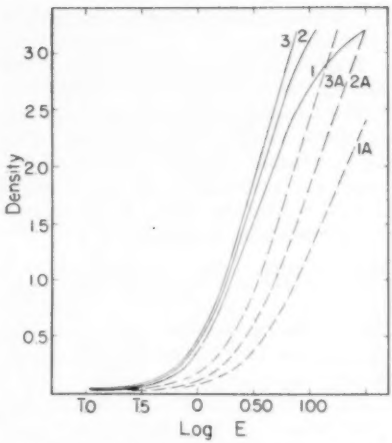

Fig. 1. Characteristic curves produced by vanadium development of Eastman Fine Grain Release Positive Film, Type 5302. Development times of 25, 30, and 35 seconds at 60 F are represented by Curves 1, 2, and 3. These are compared with development times of 3, 5, and 8 minutes at 68 F in Kodak D-16 Developer, producing Curves 1A, 2A, and 3A.

Properties of Vanadium Developer

The solution thus prepared is an extremely active developer for emulsions such as Eastman Fine Grain Release Positive, Type 5302. As shown in Fig. 1, developing for times ranging from 25 to 35 sec will produce sensitometric curves very similar to those produced in 3 to 8 min in a conventional Metol-hydroquinone developer, such as Kodak D-16. The vanadium development gives substantial increases in speed, amounting to more than twice that

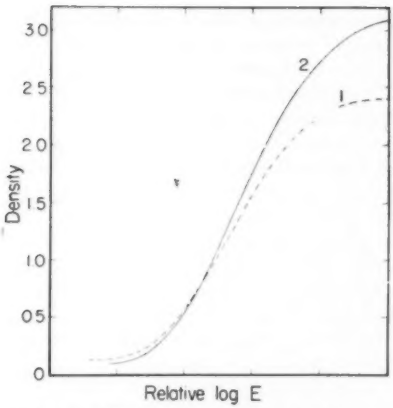

Fig. 2. Effect of degree of agitation on vanadium development. Curve 1 was produced by still development, and Curve 2 using high agitation for the same time of development.

produced by the conventional developer. There is some tendency, however, for shoulder densities to be a little low and, unless proper precautions are taken, fog values will be high.

The kinetics of vanadium development were investigated extensively by L. J. Fortmiller and T. H. James, of these Laboratories, and the complete description of this work appears in a forthcoming separate article.[8] The development reaction can be most simply stated as follows:

$$V^{++} + Ag^{+} = Ag + V^{+++}. \quad (9)$$

James and Fortmiller found that the rate of development is proportional to the concentration of vanadous ion up to a concentration of 0.1 *M*, but drops somewhat below direct proportionality at higher concentrations, and the rate is essentially independent of vanadic-ion concentration. There is no significant induction period and development starts immediately. The rate of development under most practical conditions appears to be largely controlled by the rate of diffusion of developer through the gelatin layer, and therefore is markedly influenced by agitation.

The differences in sensitometric properties that can be produced by varied agitation are demonstrated by the curves in Fig. 2. When comparing high agitation with still development, it is seen that for the same time of development much higher shoulder densities and higher gamma are produced when high agitation is used.

Roman obtained best results with vanadous bromide dissolved in hydrobromic acid of about 2.35 *M* concentration. The optimum concentration of vanadous bromide was about 0.4 *M*. He also tried sulfuric and hydrochloric acid solutions of vanadium but obtained lower image densities and higher fog values.

Roman's optimum formula did not give best results with Eastman Fine Grain Release Positive Film, Type 5302, available in this country. The formula used to produce the results shown in Fig. 1 was the result of experiments in which a systematic variation of the various developer components was made.

The optimum vanadium-ion concentration was found to be 0.35 – 0.45 *M*, which is in agreement with Roman's work. However, better results could be obtained with a mixture of hydrobromic and sulfuric acids rather than by using either one alone.

Fog development varied quite widely with the sulfuric and hydrobromic acid concentrations, minimum fog values being obtained when the ratio of the equivalent sulfuric acid to hydrobromic acid concentrations was 4:1. Fog and speed values varied with the total acidity of the developer, a total acidity of 3 normal being optimum.

Combining these values, a formula containing 0.44 mole of vanadium, 80 to 85% of which is in the divalent state, 2.4 equivalents of sulfuric acid, and 0.6 equivalent of hydrobromic acid gave best results. Development of motion-picture positive-type film to normal

gamma required 15 to 25 sec. In terms of weights and volumes of starting materials, the optimum experimental formula was as follows:

Vanadium pentoxide	40 g
Hydrobromic acid (48%) . .	68 ml
Sulfuric acid (95%)	68 ml
Water to make	1 l

(28 g of oxalic acid used to dissolve the vanadium pentoxide)

Since this formula gave fog values somewhat higher than desired, the addition of antifoggants was investigated. Conventional organic antifoggants, such as benzotriazole and 6-nitrobenzimidazole, were ineffective but low concentrations of potassium iodide in the order of 0.05 g/l maintained fog at acceptable levels.

The temperature of development, while controlling development rate, has an appreciable effect on fog formation. Best results are obtained at a temperature of 60 F, below which there appears to be no reduction in fogging propensity.

The temperature coefficient of development is low, being about 1.5 for a 18 F (10 C) change of temperature. However, the temperature coefficient of fog development is higher than that of image development and therefore the developer has less selectivity at higher temperatures.

The characteristics of images produced by vanadium development show some marked differences from those produced by conventional developers. Photomicrographs of cross sections of a vanadium-developed image show that image silver tends to be concentrated more toward the surface of the emulsion than is the case with conventionally developed images. Where there is high fog, silver is deposited predominantly near the base, and the extent of this fog silver varies inversely with the amount of image silver produced.

The image tone produced by vanadium development is somewhat colder than that produced by conventional development but the graininess of the two images remains essentially equal. In terms of speed-graininess ratio, vanadium development appears to give a considerable improvement over conventional processing.

The relatively high acid concentration of the vanadium developer is necessary to prevent hydrolysis of the vanadous ion and subsequent precipitation. The high acidity will cause serious swelling or solution of the gelatin unless the photographic emulsion used is prepared with hardened gelatin, or is hardened before development.

The physical stability of fine-grain positive emulsions when processed in vanadium solutions is excellent, despite the extreme acidity of the solution. This is due, in part, to the short development time, the low temperature of processing, and the hardening action of the vanadium ion. If the temperature of processing is raised to 75 F, softening and reticulation of the emulsion may occur even during the short developing times.

A Vanadium Processing Machine

The various experiments leading to the results already described were made using hand-processing techniques. As a step toward reducing the vanadium development system to practice, a small continuous processing machine was built for processing projection lengths of motion-picture prints. Because of the highly corrosive nature of the vanadium developer solution, the developing section must be made from noncorroding materials, such as Plexiglas and Type 316 stainless steel. Figure 3 is a schematic representation of the vanadium processor.

Immersed-jet agitation is used in the developing tank and the developer from the tank flows through an electrolytic cell similar to that already described. The developer is pumped from the cell through a thermostatically controlled

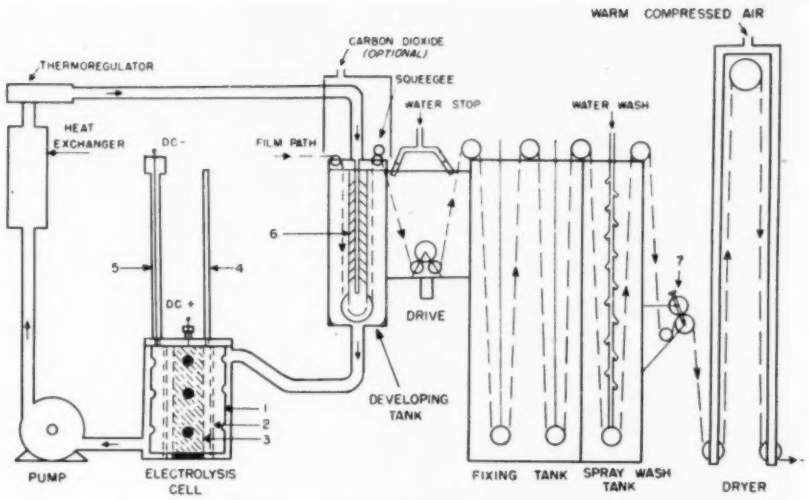

Fig. 3. Schematic representation of vanadium processing machine: 1, lead cathode; 2, porous cup; 3, carbon anode; 4, vent:anode compartment; 5, vent:cathode compartment; 6, column of orifices through which developer is forced to give immersed-jet agitation; 7, drive and squeegee. Arrows in developer recirculation system show the direction of solution flow. The electrolysis cell, the developing tank, and the drying cabinet are of Plexiglas, while all other parts that come in contact with solutions are of Type 316 stainless steel.

heat-exchange system back to the immersed jets of the developing tank.

The electrolytic cell in the system serves as a novel method of maintaining developer activity. Oxidized vanadium formed by the development process and aeration is electrolytically reduced in the cell and the composition of the developer remains essentially constant. The only loss is represented by the amount of solution carried out on the film, and with proper squeegeeing, this may be kept at a low level. Runs have been made where carry-out rates of approximately 0.3 ml/ft of 35mm film have prevailed.

After development, the film immediately passes through a spray water rinse which acts as a stop bath. From this point, the film is conventionally fixed, washed and dried, except that an ammonium hypo fixer, spray wash and warm, forced-air current are employed, so that the rate of these processing steps will be consistent with the developing rate. Figures 4 and 5 show the experimental machine with which the vanadium development tests were made.

Processing Procedure

Using the optimum vanadium developer formula, Eastman Fine Grain Release Positive Film, Type 5302, is developed in 15 to 20 sec at 60 F on the experimental machine with a film speed of about 6 ft/min. The developing section is charged with a solution prepared in an external electrolytic cell, the electrolysis being performed external to the machine primarily to save time. Continuous electrolytic regeneration of the vanadium developer during a processing run requires relatively little current and consequently the electrolytic

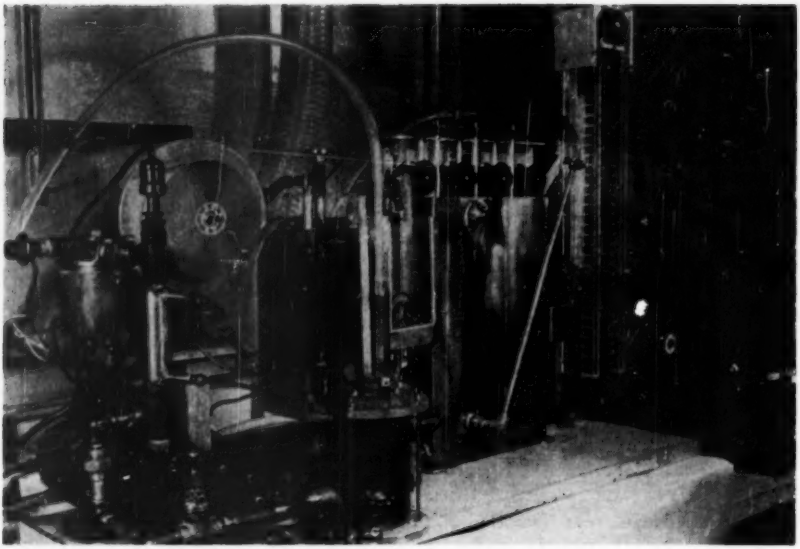

Fig. 4. General view of vanadium processing machine.

cell in the machine need not have a very high capacity. However, if the machine were filled with unelectrolyzed developer at the start, it would require an unreasonable amount of time to bring the solution up to proper activity with the low-capacity machine cell.

Replenishment to maintain volume of solution in the system can be made with either the electrolyzed or non-electrolyzed solution. The replenisher solution has essentially the same composition as the starting solution, with the possible exception of a slightly lower bromide concentration. At the carry-out rates found on the machine, as much as 3300 ft of 35mm film can be processed in 1 liter of vanadium developer solution. The bromide build-up in the developer caused by this high processing capacity will be at least partially compensated for by the electrolysis. Bromide ion diffusing into the anode compartment of the machine cell is oxidized to bromine gas and thus removed from the system. If this is not enough, the composition of the replenisher solution is adjusted accordingly.

Runs of up to 8000 ft have been made on the processing machine using Eastman Fine Grain Release Positive Film, Type 5302. Electrolytic regeneration of the developer was used, as already described, to maintain developer activity, and throughout the run it was possible to produce reasonably constant photographic results.

To keep a check on the developer composition during processing, an analysis procedure has been devised that requires no more equipment, time and skill than the procedure used in control analysis currently practiced by motion-picture processing laboratories.

There appears to be no necessity for special techniques in processing other than to observe the following precaution. Since the vanadium solution is very sensitive to aerial oxidation, care must be taken to prevent undue exposure to air, otherwise very rapid oxidation of the developer will occur and there will be a tendency for aerial fogging reactions.

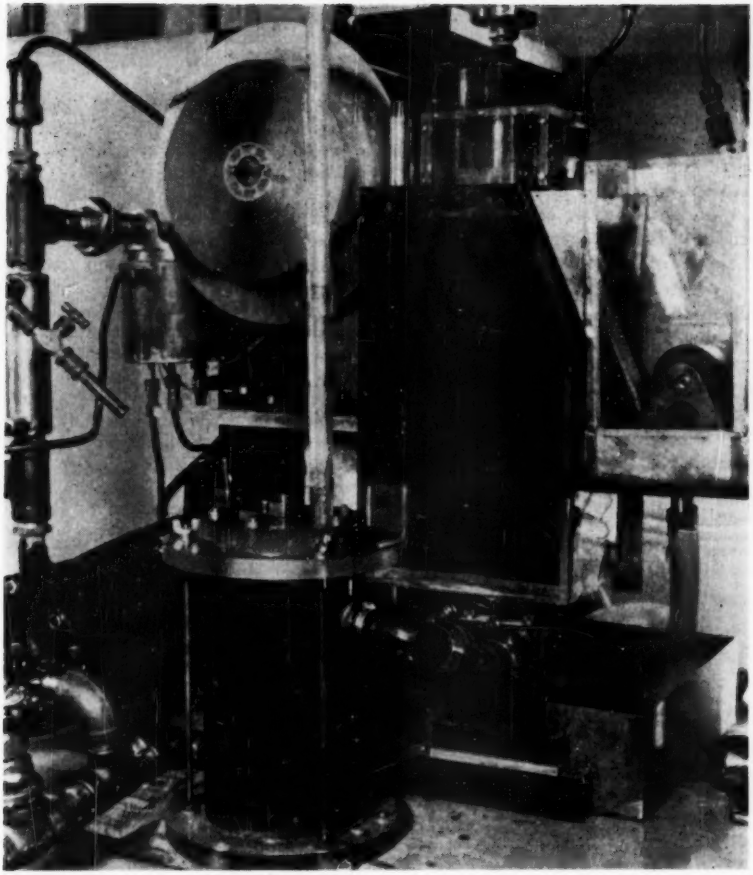

Fig. 5. Developing and regeneration sections of vanadium processing machine.

A carbon dioxide gas blanket was maintained over the developing-tank head on the experimental machine since there was a tendency for air to be sucked into the system. It is believed, however, that an improvement in design will eliminate this necessity and the slight oxidation that would occur could be balanced by electrolytic regeneration.

Potential Applications

At present, the only potential users of the vanadium system for processing motion-picture positive film are the large-scale laboratories that already have the facilities and skilled personnel necessary. The advantages of rapid development rate, effective speed increase, improved image tone, and high capacity of the vanadium development system are offset by the necessity of handling a corrosive solution, a noxious gas, and using special equipment. Further study and development will be necessary to determine the ultimate practicability of the vanadium system

but it represents a pioneering effort in the use of inorganic salts for developing photographic emulsions.

Although this paper has dealt mainly with the processing of positive emulsions, some results have been obtained in other applications. In general, results with high-speed negative emulsions have been much poorer, at least when using the optimum vanadium formula mentioned. The large speed increases associated with processing positive films have not been obtained in these cases. Better results have been obtained when processing fine-grain recording materials, such as Kodak Recordak and Microfile films, but more complete tests with a wide variety of emulsions are in progress.

Acknowledgment

The authors are indebted to C. J. Kunz for assistance in the design of the processor.

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Discussion

John A. Maurer (*J. A. Maurer, Inc.*):It was mentioned that no sound track was made on this film. It was also mentioned during the paper that the vanadium has a hardening effect on the portion of the film where the image is developed. Of course, we're all familiar with the fact that in ordinary development an image in relief is generally produced. This relief image can be seen while the film is still wet. This action is accompanied by certain dimensional changes in the image which in the literature go by the name of the Ross effect, and which, in many cases, introduce distortion in sound recorded on film. Have any observations been made as to the magnitude of the Ross effect in the vanadium development?

Mr. Rasch: We haven't made any specific investigations of that effect but the sound-track quality for variable-area sound is at least equal to that of conventional processing. From the standpoint of variable-density recording, higher intermodulation distortion levels were found.

Tom Hill (*Ringwood Chemical Corp., Ringwood, Ill.*): What provisions or plans have been made for neutralizing or removing from the premises the by-product bromine gas?

Mr. Rasch: The amount of bromine gas coming off was extremely small and we could get rid of it by turning it into the regular flues of the Research Laboratories. However, we have run tests in which a hydrobromic acid solution was used as the anolyte and in that case we get a much greater volume of bromine gas. However, bromine gas is absorbed very readily in a sodium carbonate solution with the release of carbon dioxide.

A Mathematical Approach to Replenishment Techniques

By SAMUEL R. GOLDWASSER

Equations are derived for use in calculating formulas and rates of addition of replenisher solutions. Replenishment formulas and rates are determined not only by chemical reactions between constituents of the film and the solutions, but also by physical characteristics of the equipment in which the film is processed. When values for carry-over, tank volume, overflow, film velocity-chemical activity, and concentration levels are inserted in appropriate equations, replenisher formulas and rates can be calculated. The application of the equations to a typical problem is shown.

In processing motion-picture film, it is common practice to renew solutions in the developing machines by the use of replenishment systems. Physical and chemical changes take place in the various solutions as film is processed, and the used solutions, instead of being discarded, are replenished continuously and automatically. The replenishers balance out changes occurring in the solutions which would affect sensitometric properties of the film. In black-and-white systems, each developer and hypo solution is generally replenished, while in color systems each developer, hypo, prebath, short-stop, bleach and stabilizer solution is likely to be replenished.

Presented on October 6, 1953, at the Society's Convention at New York by Samuel R. Goldwasser, Laboratory Branch, Signal Corps Pictorial Center, Long Island City 1, N.Y.
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Studies of replenishment technique in the past have been devoted primarily to developer solutions. The emphasis on developer solutions arose because small changes in composition of the developer affect the gamma and density of film markedly, while small variations in composition of the other solutions do not appear to exert such conspicuous and measurable effects. Although deviation of a nondeveloper solution from its original formula may show no immediate effect, such variation has been known to cause blurring of images and fading of colors after passage of time.

Past replenishment studies narrowed themselves to developer solutions used in certain limited ways. Film is generally dry, in black-and-white systems, as it enters the developer, and previous replenishment techniques have therefore been concerned primarily with tanks where no liquid was carried into the solution by the film. Color film,

SYMBOLS

Symbol	Definition	Units
A	Rate of carry-over of liquid into tank	Gallons per foot
B	Rate of loss of solution from tank	Gallons per foot
B_c	Rate of loss of solution from tank by carry-over	Gallons per foot
B_o	Rate of loss of solution from tank by overflow	Gallons per foot
C	Concentration	Grams per liter
C_o	Desired concentration of constituent in processing solution	Grams per liter
C_r	Concentration of constituent in replenisher solution	Grams per liter
$+D$	Rate of removal of constituent from solution due to chemical reaction	Grams per foot
$-D$	Rate of addition of constituent to solution due to chemical reaction	Grams per foot
f	Quantity of leader or film	Feet
R	Rate of addition of replenisher solution	Milliliters per minute
T	Tank capacity	Gallons
V	Rate of passage of film through machine	Feet per minute
W	Quantity of constituent in tank	Grams
W_o	Initial quantity of constituent in tank	Grams
W_r	Quantity of constituent in replenisher	Grams

however, is often wet when it reaches the developer, and the amount of liquid carried in by the entering film does affect the formulation of the replenisher and the rate at which it should be pumped into the developer tank.

Empirical methods have generally been used in establishing replenishment formulas and rates. In commenting on a paper by Evans[1] dealing with calculation of developer concentrations, Townsley[2] reported that the "cut and try" method of establishing a replenishment technique had worked well in his laboratory. Townsley indicated that over 25,000 ft of 16mm film had been processed weekly for 18 months, and required no adjustments in developing time or replenishment rate. Baumbach[3] described replenishment techniques which had also proved quite workable. He reported that occasionally, in an unpredictable way, processing solutions strayed from the desired concentration levels, so that they had to be readjusted. Baumbach also indicated that close sensitometric and chemical control had to be employed in order to detect trends away from gamma and density standards.

Bates and Runyan[4] described replenishment techniques which "were formulated using solution-analysis techniques" and proved successful "when used in combination with photographic and analysis tests." The schedule of analyses listed by Bates and Runyan included sensitometric tests every 15 min; temperature and *pH* checks every hour; bromide analyses every 4 hr; ferrocyanide analyses, specific gravity and silver analyses every 8 hr; and complete developer analyses every 48 hr.

Empirical methods have proved unsuccessful in some respects. A replenishment technique developed empirically will always work well for the particular operating conditions under which it was developed. When small changes in operating procedure, such as a readjustment of machine speed, are made, uncertainty about the effects makes it necessary to follow closely with control tests. New situations, such as a change from original negative to dupe negative, require that the trial-and-error process of finding a new replenishment rate start again right from the beginning. Also, empirical methods tend to be

costly. As long as the desired results are gained, attention is given to expense in only a secondary way. Because the main object is to produce film meeting quality standards, and because silver recovery provides substantial returns, expenditures for raw materials are regarded as of minor importance. Consequently, a replenishment system which consumes tremendous quantities of chemicals and requires extensive control testing is considered, nevertheless, successful as long as film which satisfies quality requirements is produced. In an effort to deal with the problem of quality control without resorting to excessive use of chemicals or labor, the problem of replenishment is approached here by analyzing the process in terms of the basic factors involved.

Chemicals lost from processing solutions as film is processed must be replaced by the replenishers at the same rate at which they are lost. Similarly, those gained during processing must concurrently be eliminated, through the action of the replenishers. Carry-over of liquid by the film, and reaction between film and solution chemicals, cause the main changes in composition of the processing solutions. If rates of carry-over and reaction in a system are known, then it is a simple matter to calculate the replenishment that a system demands. These rates cannot always be measured directly, but equations can be formulated which express them in terms of measurable quantities. The first portion of this paper deals with the methods of determining rates of carry-over and reaction, while the latter portion shows how these values may be applied in calculating replenishment rates and formulas.

Determination of Carry-Over Rates

When wet leader enters and passes through a solution, the concentration of each chemical in the solution becomes reduced, even though no chemical reactions occur. Water carried in by the leader dilutes the solution, while liquid carried out by the leader withdraws chemicals from the solution. If the symbol W represents quantity of a constituent in a tank, and if f represents the number of feet of leader entering and leaving the tank, then the derivative dW/df represents the rate of loss of constituent from the tank. A constituent removed from a tank by carry-over is lost at a rate equal to the product of the rate of loss of liquid from the tank (B) and the concentration of the constituent at that particular time. It is possible to express concentration in terms of quantity of constituent (W) and volume of liquid in the tank. How much liquid is present in a tank after f ft of leader have passed through it? This volume is determined by the volume of liquid in the tank initially (T), the carry-over of liquid into the tank (Af), and the loss of liquid from the tank by carry-over at the exit (Bf). When concentration is expressed by the equivalent term, the following differential equation[5] may be set up to describe the rate of loss of a constituent from a tank as a result of carry-over:

$$\frac{dW}{df} = \frac{-W}{T + (A - B)f} B \qquad (1)$$

Equation 1 may be solved in the following way[5]:

$$\frac{dW}{W} = \frac{-B\,df}{T + (A - B)f} \qquad (2)$$

$$\ln \frac{W}{W_o} = \frac{-B}{A - B} \ln \frac{T + (A - B)f}{T} \qquad (3)$$

$$\frac{W}{W_o} = \left[\frac{T}{T + (A - B)f}\right]^{\frac{B}{A-B}} \qquad (4)$$

$$\frac{C}{C_o} = \left[\frac{T}{T + (A - B)f}\right]^{\frac{A}{A-B}} \qquad (5)$$

Although a complex relationship, involving an exponential term, exists between carry-over and concentration,

simpler expressions can be deduced for systems common in motion-picture developing machines. In some tanks, the leader is dry when it enters, so that the carry-in rate, A, is zero. It is evident that in such tanks the concentration remains constantly at C_o. In other tanks of processing machines, the rate at which water is introduced into the tank by carry-over is equal to the rate at which solution is removed from the tank (i.e., A is equal to B). A differential equation may be set up describing this condition, and solved as follows:

$$\frac{dW}{df} = \frac{-WB}{T} \tag{6}$$

$$\frac{dW}{W} = \frac{-B\,df}{T} \tag{7}$$

$$\ln \frac{W}{W_o} = \frac{-Bf}{T} \tag{8}$$

$$\frac{W}{W_o} = e^{\frac{-Bf}{T}} \tag{9}$$

$$\frac{C}{C_o} = e^{\frac{-Bf}{T}} = e^{\frac{-Af}{T}} \tag{10}$$

This equation applies as long as the carry-over rate at the entrance is at least equal to the carry-over rate at the exit. The carry-in rate and carry-out rate are equal, for example, when rollers at the entrance and exit ends of a tank are positioned at the same height, and no hardening action takes place in the tank. The carry-in rate exceeds the carry-out rate when, for example, a tank is equipped with a squeegee at the exit end, but not at the entrance. Liquid then overflows from the tank, and despite the difference in carry-over rates, the rates of loss and gain of liquid nevertheless remain equal, so that the equation still applies. Figure 1 summarizes the relations between concentration, carry-over rates, tank volume, and footage for the different tanks. Sodium sulfate, sodium acetate and glycerol may be cited as examples of chemicals depleted by film primarily because of carry-over.

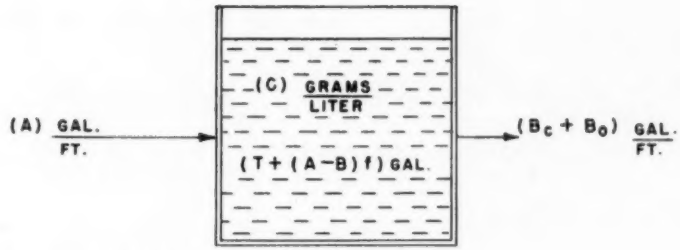
Before replenisher formulas and rates can be calculated, values of carry-in (A) and carry-out (B) rates must be obtained. Only the simplest methods of determining carry-over rates are mentioned here, but more involved methods may prove more precise. A measured quantity of film is first passed through the machine. If the volume of solution in the tank changes, measurement of the drop in level of the solution or the amount of liquid needed to maintain a constant level will indicate the net liquid loss. Also, both before and after the film is passed through, the solution is analyzed for one of the nonreactive constituents. The value of A, for the general type of tank, may then be calculated when these figures are substituted in Eq. (5), expressed in the form:

$$A = \frac{\text{Volume Change}}{f} \times \frac{\log C_o - \log C}{\log T - \log (T - \text{Volume Change})} \tag{11}$$

The volume reduction per unit length of film represents the difference between carry-in (A) and carry-out (B) rates. In tanks where the film is dry at the entrance, A is zero, and B therefore is equal to the volume loss divided by the quantity of film. In those tanks where the liquid level remains constant, values of A and B can be calculated from Eq. (10) expressed in the form:

$$A = B = \frac{T}{f} \ln \frac{C_o}{C} \tag{12}$$

If the solution overflows, then the liquid loss rate (B) calculated from this equation includes both the carry-over rate at the exit (B_e) and the overflow rate (B_o). Since the overflow can be readily collected and measured, the value of overflow per foot of film can be calculated. The difference between carry-in and overflow rates indicates the carry-out rate. Most machines are operated over a range of speeds, and so values of



Equation I: (General)

$$A = \frac{\text{Volume Change}}{f} \cdot \frac{\log C_o - \log C}{\log T - \log (T - \text{Volume Change})}$$

$$\frac{C}{C_o} = \left[\frac{T}{T + (A - B)f} \right]^{\frac{A}{A-B}}$$

Equation II: $(A = O)$

$$B = \frac{\text{Volume Change}}{f}$$

$$\frac{C}{C_o} = 1$$

Equation III: $(A = B)$

$$A = \frac{T}{f} \ln \frac{C_o}{C} = B$$

$$\frac{C}{C_o} = e^{\frac{-Af}{T}}$$

Fig. 1. Concentration of a constituent after passage of leader.

A and B should be determined for several speeds.

Determination of Reaction Rates (Chemicals Consumed)

Chemical reactions between constituents of the film and solutions also change concentrations. Elon, sodium thiosulfate and potassium ferricyanide may be cited as some of the chemicals which are consumed in chemical reaction with constituents of the film. Although such chemicals react in complex ways, the quantity of each constituent which a foot of film removes tends to assume an average value. Since the rate of removal of a constituent by chemical action can be considered constant, a symbol (D) serves to indicate the amount of a chemical consumed by a unit quantity of film. When the rate of loss caused by chemical action is added to that caused by carry-over, an expression is obtained which describes the rate of loss resulting from the combined effects:

$$\frac{dW}{df} = \frac{-WB}{T + (A - B)f} - D \quad (13)$$

This equation may be solved as follows:

$$\frac{dW}{df} + \frac{B}{T + (A - B)f} W = -D \quad (14)$$

$$(T + (A - B)f)^{\frac{B}{A-B}} W = \int (-D)(T + (A - B)f)^{\frac{B}{A-B}} df \quad (15)$$

$$(T + (A - B)f)^{\frac{B}{A-B}} W = \frac{-D}{A}(T + (A - B)f)^{\frac{A}{A-B}} + K \quad (16)$$

$$(T + (A - B)f)^{\frac{B}{A-B}} W = \frac{-D}{A}(T + (A - B)f)^{\frac{A}{A-B}} + T^{\frac{B}{A-B}} W_o + \frac{D}{A} T^{\frac{A}{A-B}} \quad (17)$$

$$(T + (A - B)f)^{\frac{A}{A-B}}C = \frac{-D}{A}(T + (A - B)f)^{\frac{A}{A-B}} + T^{\frac{A}{A-B}}C_o + \frac{D}{A}T^{\frac{A}{A-B}} \quad (18)$$

$$C = \frac{-D}{A} + \left(C_o + \frac{D}{A}\right) \times \left(\frac{T}{T + (A - B)f}\right)^{\frac{A}{A-B}} \quad (19)$$

When solved for D, this equation then appears as:

$$D = A\frac{C_o T^{\frac{A}{A-B}} - C(T + (A - B)f)^{\frac{A}{A-B}}}{(T + (A - B)f)^{\frac{A}{A-B}} - T^{\frac{A}{A-B}}} \quad (20)$$

In tanks where the film is dry when it enters, the differential equation takes the form:

$$\frac{dW}{df} = \frac{-WB}{T - Bf} - D \quad (21)$$

This may be solved as follows:

$$\frac{dW}{df} + \frac{B}{T - Bf}W = -D \quad (22)$$

$$\frac{W}{T - Bf} = \int \frac{-D}{T - Bf}df \quad (23)$$

$$\frac{W}{T - Bf} = \frac{D}{B}\ln\frac{T - Bf}{T} + \frac{W_o}{T} \quad (24)$$

$$C = C_o - \frac{D}{B}\ln\frac{T}{T - Bf} \quad (25)$$

When solved for D, the equation then appears as:

$$D = \frac{B(C_o - C)}{\ln T - \ln(T - Bf)} \quad (26)$$

In those tanks where the rate of gain of liquid exactly equals the rate of loss of solution (so that $A = B$), the differential equation is:

$$\frac{dW}{df} = \frac{-WB}{T} - D \quad (27)$$

and may be solved by the following steps:

$$\frac{dW}{WB + TD} = \frac{-df}{T} \quad (28)$$

$$\frac{1}{B}\ln\frac{WB + TD}{W_oB + TD} = \frac{-f}{T} \quad (29)$$

$$C = \frac{W}{T} = e^{\frac{-Bf}{T}}\left(C_o + \frac{D}{B}\right) - \frac{D}{B} \quad (30)$$

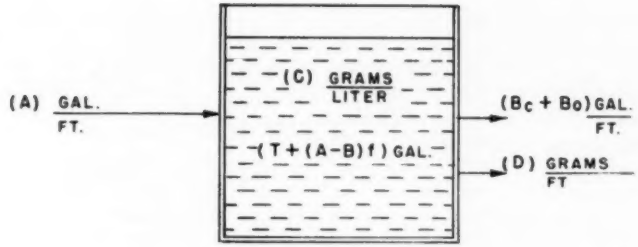
Or when solved for D, this equation is expressed as:

$$D = B(C_o e^{\frac{-Bf}{T}} - C)(1 - e^{\frac{-Bf}{T}})^{-1} \quad (31)$$

Values of D may be obtained by methods similar to those used in determining A and B. The solution is analyzed for a constituent, both before and after a known amount of film is processed. Values of tank volume (V), concentration (C and C_o), footage (f), carry-in rate (A), and carry-out rate (B) are then substituted in the appropriate equation—whichever one applies for the particular tank—and the equation is solved for D. A summary of the equations which may be used in calculating D for this type of chemical is listed in Fig. 2.

Determination of Reaction Rates (Chemicals Added)

When film passes through processing solutions, certain constituents are added to the solutions, rather than withdrawn, as a result of chemical action. Potassium bromide, silver thiosulfate, and potassium ferrocyanide are the most prominent examples of the chemicals showing this type of behavior. The differential equations for such constituents may be set up, and solved, in the same way as for constituents depleted by chemical action, except that in this case D may be considered to have a negative sign. Values of D for these



Equation IV: (General)

$$D = (-A)\left(C_o T^{\frac{A}{A-B}} - C(T + (A-B)f)^{\frac{A}{A-B}}\right) \Big/ \left(T^{\frac{A}{A-B}} - (T + (A-B)f)^{\frac{A}{A-B}}\right)$$

$$C = \frac{-D}{A} + \left(C_o + \frac{D}{A}\right)\left(\frac{T}{T + (A-B)f}\right)^{\frac{A}{A-B}}$$

Equation V: $(A = O)$

$$D = B\,\frac{(C_o - C)}{\ln T - \ln(T - Bf)}$$

$$C = C_o - \frac{D}{B}\ln\frac{T}{T - Bf}$$

Equation VI: $(A = B_c)$

$$D = A\left(C_o e^{\frac{-Af}{T}} - C\right)\left(1 - e^{\frac{-Af}{T}}\right)^{-1}$$

$$C = e^{\frac{-Af}{T}}\left(C_o + \frac{D}{A}\right) - \frac{D}{A}$$

Fig. 2. Concentration of a constituent after passage of film. Constituent is depleted by chemical reaction and by carry-over.

constituents may be calculated from the equations listed in Fig. 3.

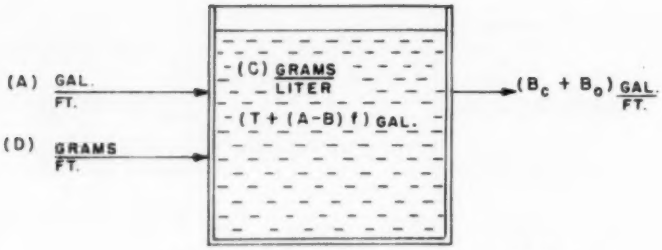
Calculation of Replenishment Rates and Formulas

Processing solutions that are maintained constantly at the concentration values of the original formula—or a "seasoned solution" formula—can be expected to produce film of unchanging photographic qualities. The ideal replenishment system will constantly counterbalance dilution and contamination effects of film, and thereby continuously restore constituents of the processing solutions to concentrations of the basic formula. A chemical removed from the solution by carry-over, overflow or chemical action must be supplied by the replenisher at the same rate at which it is lost; a chemical added to the solution as a result of film passage must be removed by replenishment action at the rate at which it tends to build up. The equality which should exist between the replenishment rate and the exhaustion rate may be expressed mathematically. If the weight of chemical in a tank at any time is W, film footage is f, velocity of film passage is V, concentration of chemical in replenisher is C_r, and rate (in time) of addition of the replenisher solution is R, then:

$$C_r R = -\frac{dW}{df}V \qquad (32)$$

The term dW/df must now be evaluated.

The rate of loss, and therefore the rate of replenishment, of a nonreactive constituent depends on concentration of the chemical and on rate of removal of the liquid from the tank. It was shown previously that the rate at which a nonreactive chemical is lost can be expressed by the following equation:



Equation VII: (General)

$$D = (A)\left(\frac{C_o T^{\frac{A}{A-B}} - C(T+(A-B)f)^{\frac{A}{A-B}}}{T^{\frac{A}{A-B}} - (T+(A-B)f)^{\frac{A}{A-B}}}\right)$$

$$C = \frac{D}{A} + \left(C_o - \frac{D}{A}\right)\left(\frac{T}{T+(A-B)f}\right)^{\frac{A}{A-B}}$$

Equation VIII: $(A = O)$

$$D = B\,\frac{(C - C_o)}{\ln T - \ln(T - Bf)}$$

$$C = C_o + \frac{D}{B}\ln\frac{T}{T - Bf}$$

Equation IX: $(A = B)$

$$D = A\left(C - C_o e^{\frac{-Af}{T}}\right)\left(1 - e^{\frac{-Af}{T}}\right)^{-1}$$

$$C = e^{\frac{-Af}{T}}\left(C_o - \frac{D}{A}\right) + \frac{D}{A}$$

Fig. 3. Concentration of a constituent after passage of film. Constituent is added to solution by film and is depleted by carry-over.

$$\frac{dW}{df} = \frac{-WB}{T + (A - B)f} \qquad (33)$$

in which A is the volume of liquid carried into the tank per foot of film, B is the volume of solution carried out of the tank per foot, and T is the initial volume. In continuous replenishment, only an infinitesimal change of concentration or volume should occur before the replenisher restores the solution to its original condition. The value of $\frac{W}{T + (A - B)f}$ therefore centers about C_o, and consequently:

$$C_r R = BC_o V \qquad (34)$$

It is also possible to derive Eq. (34) by starting with the differential equation:

$$\frac{dW}{df} = \frac{C_r R}{V} - \frac{WB}{T + \left(\frac{R}{V} + A - B\right)f} = 0$$

and then substituting C_o for the term $\frac{W}{T + \left(\frac{R}{V} + A - B\right)f}$.

The constant B, representing the total amount of solution lost from the tank as one foot of film passes through, includes the solution carried out by the film (B_c) as well as the solution overflowing from the tank (B_o). The rate of overflow is determined not only by the carry-over at the entrance (A) and the exit (B_c) but also by the rate of addition of the replenisher solution (R). As long as the solution in the tank is maintained at the same level, the rates of admission and removal of liquid are equal, and the following equality may therefore be expressed:

$$R + AV = BV = (B_c + B_o)V \qquad (35)$$

where R indicates volume of replenisher

solution added per unit of time. The replenisher equation may now be rewritten with the $B \cdot V$ term replaced:

$$C_r R = C_o BV = C_o(B_c + B_o)V = C_o R + C_o AV \quad (36)$$

When a constituent is involved in chemical reactions as the film is processed, it must be replenished in a way to compensate not only for the losses due to carry-over but also for the losses (or gains) due to chemical reaction. As shown previously, the rate at which chemical is removed from a tank by both carry-over and reaction may be expressed by:

$$\frac{dW}{df} = \frac{-WB}{T + (A - B)f} - D \quad (37)$$

Here, too, because continuous replenishment is used, the concentration value can be approximated:

$$C_o = \frac{W}{T + (A - B)f} \quad (38)$$

Consequently,

$$\frac{dW}{df} = -(BC_o + D) \quad (39)$$

and

$$C_r R = V(BC_o + D) = C_o R + C_o AV + DV \quad (40)$$

Where a chemical is added to the solution as a consequence of film passage, the DV term is subtracted, rather than added.

The complete replenisher formula can be calculated from the above equations after a replenishment rate (R) is established. The rate of replenishing is closely related to the rate of loss of solution overflowing from the tank. Although overflow solution is constituted in the proportions of the processing formula and contains unreacted chemicals, it generally is discarded. Losses of chemicals down the drain as a result of overflow can be minimized, therefore, by choosing as small a value of R as possible. Three factors limit the minimum value which may be chosen for R:

(1) Enough liquid must be supplied to maintain the solution at the top level of the tank. The replenisher must compensate for the water losses just as for the chemical losses, and where carry-over at the exit exceeds carry-over at the entrance, replenishment must supply the additional liquid. This requirement may be expressed by the equation:

$$R \geq (B_c - A)V \quad (41)$$

(2) Enough liquid must be supplied to dissolve all solids in the replenisher. If the replenisher must supply large quantities of a relatively insoluble chemical, the replenisher must then also contain a large amount of water, in order that the constituent will be completely dissolved. The replenishment rate may be expressed, as Eq. (40) shows, in terms of the various other factors:

$$R = \frac{C_o AV + DV}{C_r - C_o} \quad (42)$$

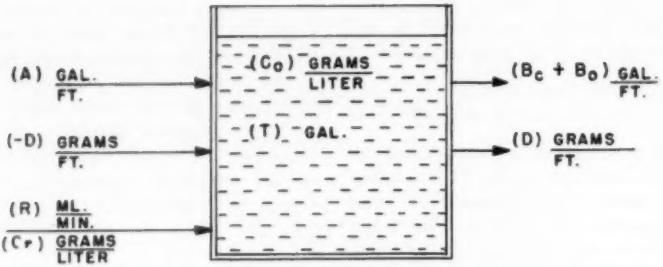
If the constituent is contained in the replenisher at its solubility limit (C_s), the minimum replenishment rate, based on solubility, would be:

$$R \geq \frac{C_o AV + DV}{C_s - C_o} \quad (43)$$

(3) Enough liquid must be supplied to minimize effects of constituents which are added to the solution as film is processed. Certain of the substances which tend to increase in concentration exert marked effects on sensitometric properties of the film. Replenisher solution must be added at a sufficiently rapid rate to dilute the solution, maintaining these constituents at a constant concentration level. When such a constituent is omitted completely from the replenisher, the minimum replenishment rate, as derived from Eq. (40), is:

$$R \geq \frac{-DV}{C_o} - AV \quad (44)$$

The replenishment rate is usually deter-



Equation X: $$C_r = \frac{(B_c + B_o)C_oV + D \cdot V}{R}$$

$$C_r = \frac{(AV + R)C_o + D \cdot V}{R}$$

$$C_r = \frac{AVC_o + D \cdot V}{R} + C_o$$

Equation XI: $$R \geq (B_c - A)V$$

Equation XII: $$R \geq \frac{C_o VA + D \cdot V}{C_r - C_o}$$

Equation XIII: $$R \geq \frac{-D \cdot V}{C_o} - AV$$

Fig. 4. Equations for calculating replenisher formulas and rates.

mined in developer solutions by the build-up of potassium bromide; in hypo solutions by the formation of silver thiosulfate; and in bleach solutions by the increased ferrocyanide content. Figure 4 summarizes the replenisher equations.

Intermittent Replenishment

Some solutions may be replenished by adding the chemicals periodically in bulk quantities, rather than by supplying them continuously, in infinitesimal amounts. An intermittent replenishment procedure may be employed where wide concentration ranges can be tolerated and where the constituents will dissolve readily. If W_o is the initial quantity of constituent in the tank, and W is the amount of chemical in the tank after f ft of film has passed, then the following equation expresses the amount of constituent (W_r) which must be supplied by the replenisher at each interval:

$$W_r = W_o - W \qquad (45)$$

Equations (17), (24) and (30) show that W can be evaluated, for each of the three types of tanks, in terms of footage, tank volume, carry-over rates and reaction rates. Consequently the quantity W_r can also be expressed in terms of these measurable quantities. When this substitution is made, it is found that, for the general type of tank, the replenisher should contain the following amount of each nonreactive constituent:

$$W_r = W_o\left(1 - \left(\frac{T}{T + (A - B)f}\right)^{\frac{B}{A-B}}\right) \qquad (46)$$

Where a constituent is consumed by chemical action, the replenisher must also contain the additional quantity:

$$\frac{D}{A}\left(T + (A - B)f - \frac{T^{\frac{A}{A-B}}}{(T + (A - B)f)^{\frac{B}{A-B}}}\right) \qquad (47)$$

In tanks where no carry-in occurs, the replenisher should contain the following amount of each chemical:

$$W_r = W_o\frac{Bf}{T} + D\left(\frac{T}{B} - f\right)\ln\frac{T}{T - Bf} \qquad (48)$$

The latter term, involving D, obviously disappears for nonreactive constituents. In tanks where the rates of gain and loss of liquid are equal, the quantity of constituent in the replenisher should be:

$$W_r = W_o\left(1 - e^{\frac{-Bf}{T}}\right) + \frac{TD}{B}\left(1 - e^{\frac{-Bf}{T}}\right) \tag{49}$$

Daily replenishment of such solutions as the glycerine stabilizer is often accomplished on the basis of this equation.

New Operating Conditions

A developing machine generally is not operated week after week at the same speed, nor are developing machines expected to process exclusively only one kind of film emulsion, film type or film size. A particular replenishment rate and formula calculated from Eq. (40) constitute optimum values for only one particular machine velocity and film; other conditions require other rates and formulas. It is impractical to change the formulation of the replenisher solution frequently, but if the replenishment rate is adjusted appropriately for each situation, the same replenisher formula may serve satisfactorily for all conditions. Expressions can be readily derived from Eq. (40) to describe the replenishment rate for a new condition, on the basis of the original replenishment rate and the parameters of the original and the new condition:

(1) When machine speed is changed, the new replenishment rate can be calculated from:

$$R = \frac{R_oV}{V_o} \cdot \frac{C_oA + D}{C_oA_o + D} \cong \frac{R_oV}{V_o} \tag{50}$$

The symbols A_o, V_o and R_o represent values obtained at the original machine speed. The replenishment rate should evidently vary in about the same proportion as the machine velocity.

(2) When type, or average density, of film is changed, the new replenishment rate should be:

$$R = R_o\frac{C_oA + D}{C_oA_o + D_o} \tag{51}$$

Values of A_o and D_o are obtained from the original film type or film density. The most critical constituent determines the values assigned for C_o, D_o and D.

(3) When leader, rather than film, is run through the machine, the replenishment rate should be:

$$R = R_o\frac{C_oA}{C_oA_o + D} \tag{52}$$

Here, too, C_o and D are based on the most critical constituent. A tank which receives dry leader would require, according to the above equation, a replenishment rate of zero. No water is brought in by the leader, and solution lost by carry-over at the exit must obviously be replaced. In this special case, replenishment can be accomplished with a solution compounded from the basic—not the replenisher—formula.

Illustration

An example will demonstrate how the replenisher equations can be used in calculating replenisher formulas and rates.

A processing solution is prepared according to the following specification:

X = 60 g/l
Y = 60 g/l
Z = 4.00 g/l

Component X does not react; component Y is consumed at the rate of 15 g/1000 ft; component Z, which must be held within the narrowest concentration range, is formed at the rate of 10 g/1000 ft. The carry-in rate is 0.15 gal/1000 ft and the carry-out rate is 0.25 gal/1000 ft. The film travels through the machine at 70 fpm. Solubility of X is 200 g/l; of Y is 140 g/l; and of Z is 10 g/l. What should the replenishment rate and formula be?

Calculations: The minimum value of R is determined:

$$R \geq V(B_e - A) \tag{53}$$

$$\geq \frac{(70)\ \frac{\text{ft}}{\text{min}}\ \frac{(0.25 - 0.15)}{(1000)}\ \frac{\text{gal}}{\text{ft}}\ (3785)\ \frac{\text{ml}}{\text{gal}}}{} \tag{54}$$

$$\geq 26.5\ \frac{\text{ml}}{\text{min}} \tag{55}$$

$$R \geq \frac{(C_o A + D)V}{C_o - C_e} \tag{56}$$

$$\geq \frac{(60)\ \frac{\text{gram}}{\text{liter}}\ \frac{(0.15)}{(1000)}\ \frac{\text{gal}}{\text{ft}}\ (3.785)\ \frac{\text{liter}}{\text{gal}} + \frac{(15)}{(1000)}\ \frac{\text{gram}}{\text{ft}}}{(140 - 60)\ \frac{\text{gram}}{\text{liter}}\ \frac{(1)}{(1000)}\ \frac{\text{liter}}{\text{ml}}}\ (70)\ \frac{\text{ft}}{\text{min}} \tag{57}$$

$$\geq 42.9\ \frac{\text{ml}}{\text{min}} \tag{58}$$

$$R \geq \frac{-DV}{C_e} - AV \tag{59}$$

$$\geq \frac{\frac{(10)}{(1000)}\ \frac{\text{gram}}{\text{ft}}\ (70)\ \frac{\text{ft}}{\text{min}}\ (1000)\ \frac{\text{ml}}{\text{liter}}}{(4)\ \frac{\text{gram}}{\text{liter}}} - \frac{(0.15)}{(1000)}\ \frac{\text{gal}}{\text{ft}}\ (3785)\ \frac{\text{ml}}{\text{gal}}\ (70)\ \frac{\text{ft}}{\text{min}} \tag{60}$$

$$= 135\ \frac{\text{ml}}{\text{min}} \tag{61}$$

The replenishment rate should therefore be 135 ml per minute.

Replenisher concentrations may now be calculated:

$$C_r = \frac{C_o(AV + R) + DV}{R} = C_o + \frac{C_o AV + DV}{R} \tag{62}$$

$$C_r = C_o + \frac{(C_o)\ \frac{\text{g}}{1}\ \frac{(0.15)}{(1000)}\ \frac{\text{gal}}{\text{ft}}\ (70)\ \frac{\text{ft}}{\text{min}}\ (3785)\ \frac{\text{ml}}{\text{gal}}}{(135)\ \frac{\text{ml}}{\text{min}}} + \frac{(D)\ \frac{\text{g}}{\text{ft}}\ (70)\ \frac{\text{ft}}{\text{min}}\ (1000)\ \frac{\text{ml}}{\text{l}}}{(135)\ \frac{\text{ml}}{\text{min}}} \tag{63}$$

$$C_r = C_o + C_o(0.295) + D(519) \tag{64}$$

	X	Y	Z
C_o	60 g/l	60 g/l	4 g/l
$C_o(0.295)$	17.7	17.7	1.18
$D(519)$	0	7.8	−5.19
C_r	77.7	85.5	0

Conclusion

Formulas and rates for continuous replenishment, and for intermittent replenishment, of solutions in developer machines can be established by methods presented here. Tank size, machine velocity, carry-over of liquid on the film, concentration values, and chemical reactions between film and solution have been shown to determine optimum replenishment formulas and rates. These controlling factors have been incorporated in equations, so that replenisher formulas and rates can be calculated readily when values of these factors are known. By means of this mathematical approach, it is believed that variation in film density and gamma caused by changes in processing solutions can be appreciably reduced, and that a savings in certain operating expenses can be attained.

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3. H. L. Baumbach, "Continuous replenishment and chemical control of motion picture developing solutions," *Jour. SMPE, 39:* 55–66, July 1942.

4. J. E. Bates and I. V. Runyan, "Processing control procedures for Ansco Color Film," *Jour. SMPE, 53:* pp. 3–24, July 1949.
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Discussion

J. I. Crabtree (*Kodak Research Laboratories*): It isn't quite clear how you calculate the amount of developing agent in the replenisher necessary to overcome the restraining action of the bromide, iodide, hydroquinone sulfonates, etc., in the exhausted developer. Secondly, how closely are your calculations correlated with practice?

Mr. Goldwasser: Gamma and density values in a seasoned solution often differ from those of the original solution because of the restraining action of products formed in development, even though the routine chemical analysis may show no difference. One way of counterbalancing the restraining effect of these products is to change the basic formula of the processing solution, for example, by raising the concentration of the developing agent (which Mr. Crabtree suggests) or by lowering the level of the bromide or iodide content. Another approach is to increase the replenishment rate above that calculated from Eq. 13 in order to hold down the concentration of these substances. I doubt whether the adjustment Mr. Crabtree speaks of can be calculated, unless it were readily possible to measure concentration values, reaction rate values, and sensitometric effects of each of the restraining products. It seems better to handle such second-order and third-order effects in an empirical manner. One can expect mathematics to bring one within the range of the optimum replenishment conditions; one cannot expect such an approach to make it possible to dispense with experimentation, sensitometric control or chemical control.

To answer the second question, experimental work is still in progress; results are not yet available.

Mr. Crabtree: That is the trouble in photography. There are so many factors involved that you cannot predict anything, precisely. The only answer is to "try it." It takes many, many years before you realize that fact.

The Effect of Camera Exposure on the Tone-Reproduction Quality of Motion Pictures

By ALLAN L. SOREM

A psychophysical study has been made of the relationship between the tone-reproduction quality of a positive motion-picture screen image and the camera exposure for the corresponding negative throughout a series of negative exposures for each of sixteen outdoor scenes and eight indoor scenes. A description is given of the method used for obtaining psychometric data, and curves are presented showing the relationship between screen image quality and the logarithm of the camera exposure. The use of these curves in determining exposure latitude, speed and exposure index is discussed.

THE EVALUATION of a photographic material from the standpoint of its ability to perform the function for which it is intended is very often based upon a study of the characteristic *D*-log *E* curve of the material. Methods of interpreting characteristic curves have been the subject of many studies and experiments in the field of photographic sensitometry, having the common objective of increasing the yield of significant information about the photographic properties of the materials which they represent. In the field of black-and-white still photography, for example, methods have been developed for obtaining and interpreting the characteristic curves of both negative films and positive reflection print materials, which permit an accurate evaluation of the photographic properties of these materials under the conditions in which they will be used in practice.

Communication No. 1617 from the Kodak Research Laboratories, by A. L. Sorem, Kodak Research Laboratories, Eastman Kodak Co., Rochester 4, N. Y. The paper was presented on October 8, 1953, at the Society's Convention at New York. (This paper was received Nov. 19, 1953.)

In pictorial photography, the final photographic image of whatever sort, black-and-white or color, reflection print or projected screen image, is but a means of producing in the mind of an observer a more or less accurate impression of the appearance of an original scene. Most physical measurements of the properties of photographic materials are fully significant only if one knows the manner in which the measured properties affect the ability of the material to produce a satisfactory impression in the mind of the observer. The sensitometrist is therefore obliged to extend his investigations outside the field of physics and into the realm of psychophysics, which deals with problems common to psychology and physics. The end product of most investigations in psychophysics is information concerning the relationship between some psychological or subjective variable and a physical or objective variable. The principles of psychophysics and its importance to photography have been thoroughly discussed by L. A. Jones,[1] who has done a great deal of pioneering work in psychophysics applied to photography.

The concept of the speed of a photographic material has inescapable psychophysical connotations. One material is usually regarded as having a higher speed than another when it will produce a satisfactory photographic image with less exposure. In order to place the concept of speed on a workable basis for black-and-white motion-picture negative films, however, a more explicit statement is required. Such a statement is the following, which is analogous to the statement regarding the concept of speed in the "American Standard Method for Determining Photographic Speed and Exposure Index," Z38.2.1-1947, applying to roll and sheet films: *The speed of a motion-picture negative film for continuous-tone black-and-white pictorial photography is inversely proportional to the minimum exposure required to produce a negative from which a positive print can be obtained that will give a projected screen image of high quality.* This definition represents a logical basis for a sensitometric speed criterion for motion-picture negative films. The necessary first step toward the realization of such a sensitometric criterion is a psychophysical study of the manner in which the quality of the projected positive screen image varies with the camera exposure given the negative.

A study has been completed using photographic reproductions of sixteen outdoor scenes and eight studio scenes. An exposure series was made of each scene on each of two black-and-white motion-picture negative materials. Exposure series of most of the outdoor scenes were also made on each of two reversal color films. The tone-reproduction quality of the final positive images obtained with each material was judged by about thirty observers. Averages of all of the judgments were obtained and used in plotting curves showing the tone-reproduction quality of the positive image as a function of the logarithm of the camera exposure.

Choice of Scenes

The scenes which were photographed were planned and constructed with two principal aims in mind. As far as possible, it was desired to conform to lighting practices followed in professional motion-picture work. It was also desired to have as much variety as possible in the types of scenes which were used. It was not difficult to meet both of these requirements for the studio scenes, but the outdoor scenes presented some problems in lighting which were caused by changes in the position of the sun during the time required to make all of the necessary exposures, meter readings and scene luminance measurements. The fill-in lighting required to reduce the ratio of highlight to shadow illumination on the models in the outdoor scenes was obtained by using reflectors. The lighting problem was somewhat simplified by the fact that the people in each scene remained motionless. Experience has shown that it is easier to evaluate the relative tone-reproduction quality of each scene in an exposure series if the people in the scene remain in one position throughout the series.

The hope has sometimes been expressed that an "average" scene could be set up which would be so nearly typical of the scene types encountered in motion-picture work that it could be used in making direct camera exposure tests, making unnecessary the considerable expenditure of time and effort required to carry out experiments involving many different scenes. There are several reasons why this is not feasible. The variables which change from scene to scene, and the combinations and interactions of these variables, are so numerous that it is practically impossible with any reasonable degree of certainty to isolate the significant variables for consideration. For example, although it is quite probable that the exposure required to produce optimum quality will depend upon the lighting ratio, the nature of this

dependence will, in turn, be affected by the relative size and importance of shadow and highlight areas.

It is probably true, also, that most observers will not be equally critical of the tone-reproduction quality in every area of a positive reproduction. Unless the observers are exceedingly conscientious and painstaking, their attention will be directed critically only to the areas which constitute the center of interest in the scene, or, for more sophisticated observers, to those areas which they feel represent the best clues to tone-reproduction quality. Moreover, because of the limitations of the photographic process, a given exposure will not, in general, produce the optimum quality in all areas of the reproduction. This is particularly true if the latitude of the photographic material is short and the range of luminances of objects in the scene is long. If a color reproduction is being studied, these considerations must be further extended to include the variation in hue and saturation of differently colored objects as the exposure is changed. It is apparent that the use of a limited number of scenes, or of a single scene which is purported to be average, may result in serious systematic errors in determining the average relationship between the overall tone-reproduction quality of reproductions and the camera exposure for a given material.

The scenes which were used are illustrated in Figs. 3 through 8. The scene areas included in these illustrations are different in some cases from those in the motion-picture prints, and the tone-reproduction quality of the reproductions is, of course, not representative of that of the projected motion-picture prints. Twelve of the sixteen outdoor scenes included people at various distances from the camera. The subjects of three of the other scenes might be classed as architectural, and the fourth was a landscape. All outdoor scenes were photographed on cloudless or nearly cloudless days to insure that the lighting would remain as nearly constant as possible during the time required for making the photographs, reading exposure meters, and making photometric measurements.

All the eight indoor scenes included at least one person. For reasons previously given, none of these scenes is regarded as "average," but, taken as a group, they include characteristics which are found in many of the indoor scenes photographed in Hollywood. Scene 20 is the same as Scene 23, but it was reconstructed and lighted with normal lighting several weeks after Scene 23 had been photographed in low key with strong backlighting. A vivid illustration of the effect of lighting variables on the apparent quality characteristics of the two films is provided by this pair of scenes.

Light Measurements

Five different exposure-meter readings were made for each scene, as follows:

(1) An incident-light measurement was made with the meter at the subject position pointed at the camera.

(2) An incident-light measurement was made with the meter at the subject position pointed toward the sun, in the case of the outdoor scenes, and, for the indoor scenes, pointed in such a direction that the highest reading was obtained.

(3) A measurement was made of the light reflected from a gray card held in front of the subject's face, perpendicular to the subject-camera axis.

(4) A meter with hemisphere was read at the subject position, with the top of the hemisphere toward the camera.

(5) A reflected-light reading was made at the camera position.

Luminance measurements were made on several areas in each scene, using a Macbeth Illuminometer modified to read the luminance of a field subtending an angle of about 10 min. Photographs

of the outdoor scenes were also made with a 5 × 7-in. camera on Kodak Super-XX Panchromatic Sheet Film which was processed with sensitometric strips exposed on an intensity-scale sensitometer, so that additional luminance values could be calculated by means of photographic photometry. The luminance measurements will be used in a future study of the tone-reproduction characteristics of high-quality black-and-white motion-picture prints. The various exposure-meter readings will be used in studying the correlation between optimum exposures and meter readings.

Photography

The indoor scenes were photographed on Eastman Background-X Panchromatic Negative Safety Film, Type 5230, and Eastman Plus-X Panchromatic Negative Safety Film, Type 5231, with a Mitchell camera running at 24 frames/sec, using either a Cooke Speed Panchro 50mm lens or a Bausch & Lomb Baltar 40mm lens. Seven exposures were usually made on each material, ranging from the equivalent of at least $1\frac{1}{2}$ stops over, to at least $1\frac{1}{2}$ stops under, the estimated optimum exposure for the scene. Thirty feet of film were exposed at each camera exposure setting. For the indoor scenes, the exposure variation was accomplished by changing the exposure time. The same combinations of aperture and exposure time were used for the two materials, and a neutral filter ($D = 0.43$) was placed in front of the lens when the faster material was being exposed.

The same camera was used in photographing the outdoor scenes, but the exposure variation within the series on each material was accomplished by changing the lens aperture. The exposure times for the two materials were different. Ideally, all of the changes in exposure should have been accomplished by changing the aperture of the taking lens, but the range of apertures available was not large enough to cover the required range of exposures. The intervals between successive exposures on each material averaged about $\frac{1}{2}$ stop.

Two additional exposure series were made of most of the outdoor scenes on Kodak Ektachrome Film, Daylight Type, and on Kodachrome Film, Daylight Type. The pictures from Ektachrome Film were made with a 5 × 7-in. camera having a calibrated shutter, from the same position as that occupied by the motion-picture camera, and using a lens giving approximately the same angular coverage as that of the motion-picture camera. The 35mm Kodachrome Film was exposed in a camera having a calibrated focal-plane shutter. The changes in exposure level for each series on the color films were made by changing the lens apertures of the cameras.

Sensitometric Exposures

Each series of exposures on the two motion-picture films was processed with sensitometric exposures made with an intensity-scale sensitometer. Sensitometric exposures were also made on each of the color materials and processed with each exposure series. A complete sensitometric record for each material is provided by these exposures.

Processing and Printing

The motion-picture negative films were processed to an average gamma of 0.65. By adjusting the printing exposure the best possible print was made on Eastman Fine Grain Release Positive Safety Film, Type 5302, from each of the negatives. The positive film was developed to a gamma of 2.6.

Densitometry

Density measurements were made of all areas in the negatives and prints corresponding to the areas for which luminance measurements had been made in the original scenes. Negative and positive step-tablet densities were also read. These data will be used in the

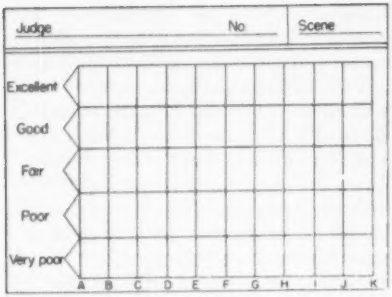

Fig. 1. Form on which observers recorded judgments of tone-reproduction quality.

study of the optimum tone-reproduction characteristics of motion-picture prints.

Judging

The prints were presented to an audience of observers in the auditorium of the Kodak Research Laboratories. A screen luminance of 10 ft-L was used. The indoor scenes were judged by 34 observers at the first viewing session, and the outdoor scenes by 32 observers at a later session. About half of the observers at each session can be classified as experts in the evaluation of tone-reproduction quality; 20% were persons with varying amounts of previous experience in making this type of judgment, who had some familiarity with the general procedure being followed; and the remaining 30% had had little or no previous experience.

Each observer was supplied with a number of forms for recording his judgments, as illustrated in Fig. 1. A separate sheet was used for each exposure series. There were 16 sheets to be filled out by each observer for the indoor scenes, and 32 sheets for the outdoor scenes. The quality scale shown at the left of the sheet is intended to embrace all levels of quality. It is divided into 5 categories: "excellent," "good," "fair," "poor" and "very poor." The observers were instructed to indicate their opinion of the quality of each scene at each exposure level by means of a short horizontal mark across the appropriate vertical line. Any number of different quality levels could be indicated within each of the labeled categories. For example, a judge might feel that all the prints of a particular exposure series were "good," although he would recognize that some were better than others. He would therefore make all of his marks at various levels within the "good" region. It can be seen that this method of recording the judgment data permits both an absolute rating of each picture according to five more or less arbitrary but mutually exclusive quality categories, as well as the rating of relative quality on a continuous scale.

The use of heavy black lines on the graphs and a very low level of general illumination made it possible for the observers to record their judgments without undue eyestrain, and without changing their level of brightness adaptation from that of the motion-picture screen.

When the indoor scenes were judged, each exposure series was presented for a preliminary viewing, after which it was presented again and the judgments were recorded. The reproductions at each exposure level remained on the screen for about 20 sec. When the outdoor scenes were presented, the preliminary viewing of the pictures from each exposure level lasted only 4 sec, and the final viewing 16 sec. It is felt that the latter procedure permitted a better overall evaluation of the quality of a particular series, while causing the observers less fatigue.

All the series were presented in the same order, ranging from prints made from overexposed negatives to those made from the negatives having the least exposure.

The exposure series on Kodachrome Film, Daylight Type, were judged by twenty observers, who used the form in Fig. 1 for recording their judgments.

The Kodachrome transparencies were projected, one at a time, with a Kodak Master Model Projector. The screen luminance was about 15 ft-L.

The Ektachrome transparencies were displayed on an illuminator having a viewing-panel luminance of 400 ft-L, in a normally lighted room, and were judged by fifteen observers, who again used the form shown in Fig. 1 for recording judgments.

Interpretation of Data

The present report is confined to a study of the curves in Figs. 3 through 8, which were derived from the judgment data, showing tone-reproduction quality as a function of the logarithm of the camera exposure. Camera exposure has been defined[2] as follows:

$$E_e = \frac{t}{f^2},$$

where E_e is camera exposure, t is time expressed in seconds, and f is the aperture ratio. Since f is dimensionless, camera exposure has the dimension of time and is expressed in seconds. A camera exposure of 1 sec can be obtained, for example, by exposing for 1 sec at $f/1$, 4 sec at $f/2$, 16 sec at $f/4$, etc.

The values of quality for each camera exposure were obtained from the judgment data by averaging the ordinates measured on the judges' sheets, and the curves in Figs. 3 through 8 were plotted. The materials represented by these curves are as follows:

A. Eastman Plus-X Panchromatic Negative Safety Film, Type 5231.
B. Eastman Background-X Panchromatic Negative Safety Film, Type 5230.
C. Kodachrome Film, Daylight Type.
D. Kodak Ektachrome Film, Daylight Type.

Figure 2 illustrates the measurements which were made on all the sets of curves, and which will be described below.

It presents two hypothetical curves showing the relationship between quality and log camera exposure for two materials, X and Y, when used to photograph the same scene. The scene characteristics which might affect the maximum quality, exposure latitude, and optimum exposure on each material have been taken into account by the judges in their quality ratings from which these curves were obtained. A direct comparison between the properties of the two materials revealed by these curves can therefore be made without further consideration of the scene characteristics. A number of similar sets of curves will provide increasingly useful information about the relative performance of the two materials.

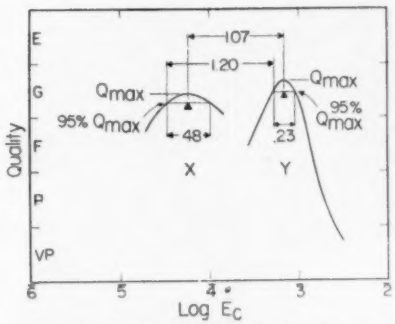

Fig. 2. Hypothetical curves showing methods of measuring latitudes, relative speeds and relative exposure indexes of two materials used to photograph the same scene. These values for this scene are respectively the antilogarithms of (a) the widths of the curves at 95% of the peak value, (b) the distance between the left ends of the horizontal lines at this level, and (c) the distance between the midpoints of these lines.

An obvious conclusion which can be drawn from an inspection of the curves in Figs. 3 through 8 is that, since the curves are fairly smooth, quality varies uniformly with log camera exposure. This is something which might not be predicted from a casual inspection of the judgment data, since there were very large differences of opinion among the judges, both as to the quality of the reproduction of any given scene and the

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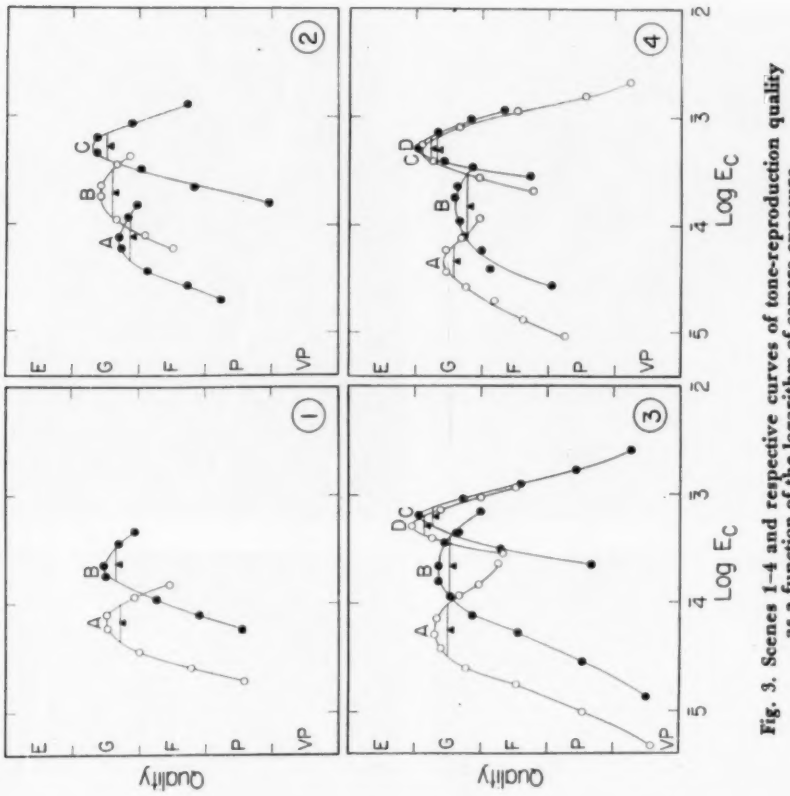
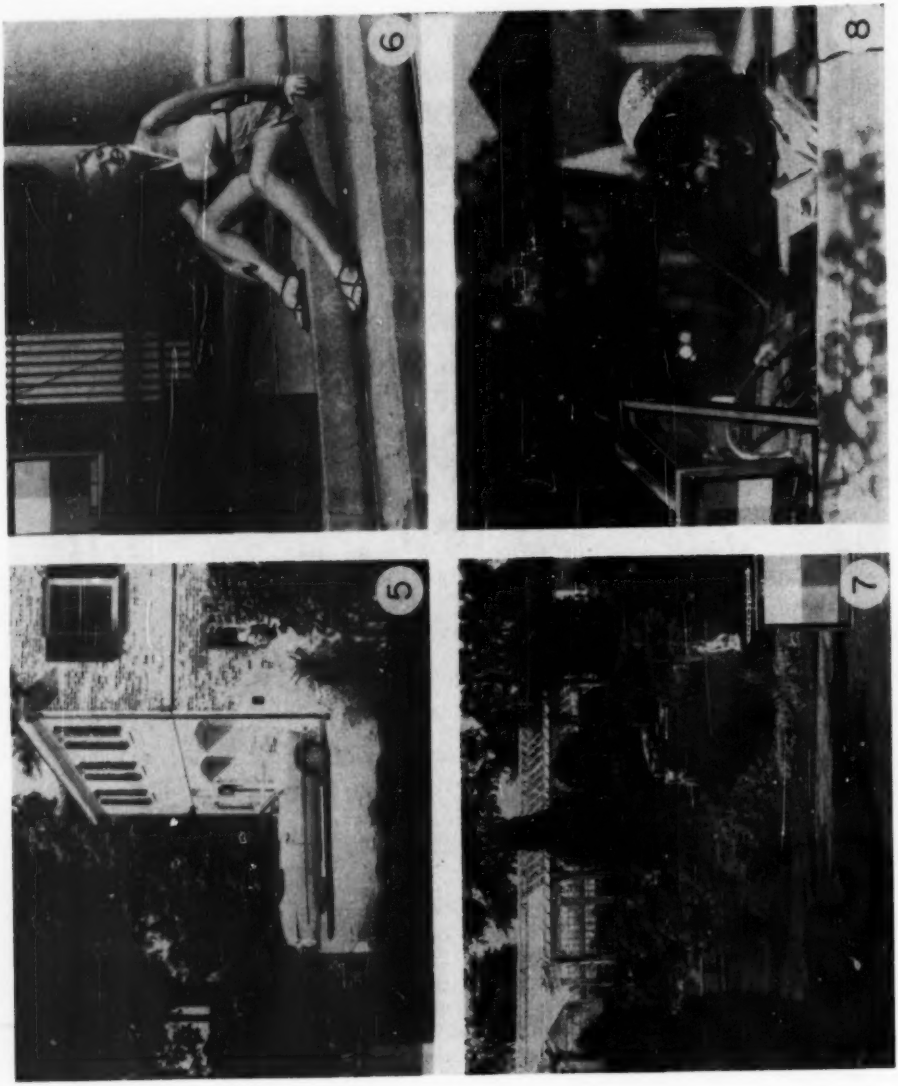


Fig. 3. Scenes 1–4 and respective curves of tone-reproduction quality as a function of the logarithm of camera exposure.

way in which the tone-reproduction quality changed with camera exposure. The smoothness of these curves also provides some assurance that there were no important errors introduced which raised or lowered the relative quality of a particular print from a negative at one camera exposure level. For example, if one of the prints in a series from a given scene had been either too light or too dark relative to the other prints in the series, the point representing this print on the quality curve might be expected to cause a deviation from a smooth curve. An inspection of the curves shows that such occurrences were very infrequent.

The first question which one might hope to answer by inspecting the curves presented here is, "What is the range of camera exposures which will yield negatives from which high-quality prints can be made?" To answer this question, the desired quality level must first be chosen. It will be noted that the peaks of a very few of the curves fall in the "excellent" region. Although many of the judges rated some of the prints from each scene as "excellent," disagreement among the judges as to which prints were "excellent," as well as the fact that some judges gave all the prints a lower rating, produced an overall rating of "good" for the prints in the vicinity of the peak of the curves in most cases. It is likely that the variations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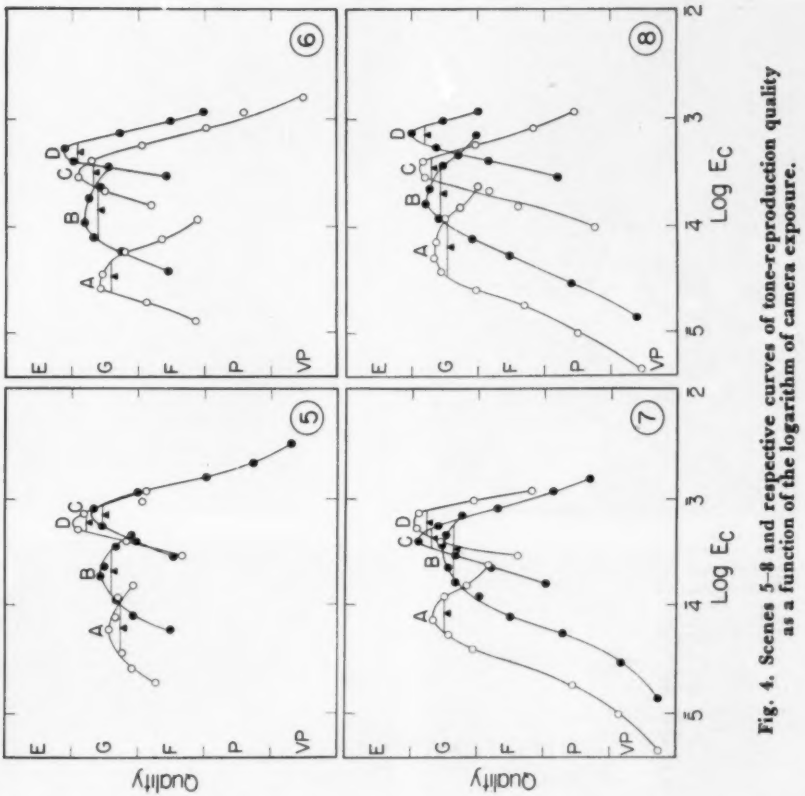
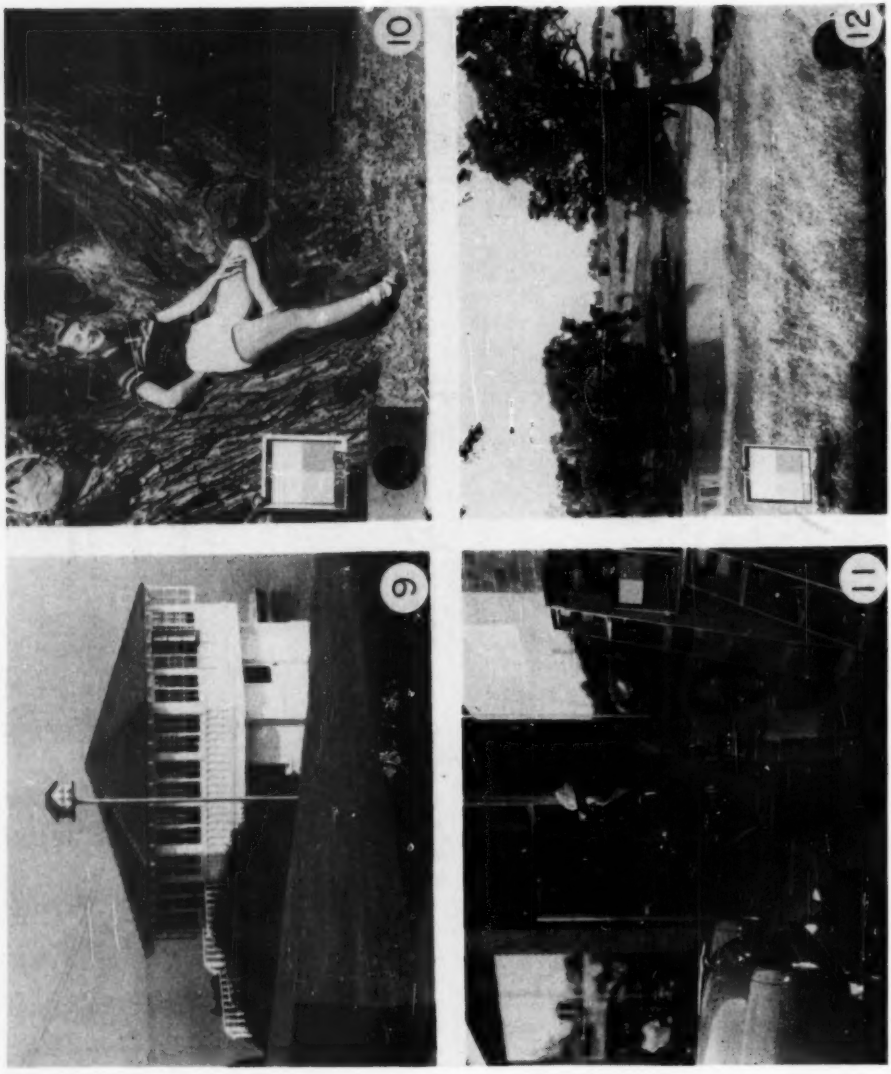


Fig. 4. Scenes 5–8 and respective curves of tone-reproduction quality as a function of the logarithm of camera exposure.

from scene to scene of the peak quality obtained with each material are partly the result of the observers being influenced more or less unconsciously by the nature of the scene itself. In other words, the best possible reproduction of a very pleasing scene may be rated higher, on the average, than the best possible reproduction of a scene which is less pleasing. However, it would be difficult, if not altogether incorrect, to attempt to estimate the extent to which this had occurred and make corrections for it by adjusting the curves upward or downward. The best way to avoid systematic errors which might originate in this way is to use a large number of scenes. For a given scene, the relative maximum qualities obtained with the various materials is, of course, a significant indication of the tone-reproduction characteristics of the materials, since any subjective influence which the scene itself might have exerted on the observers is canceled out in comparing curves for the same scene.

When curves such as these are available, for which the ordinates represent absolute levels of quality, there are at least two ways of determining the range of camera exposures over which "high-quality" prints can be obtained. The first is to locate the points on either side of the peak of each curve at a certain fixed quality level. The second is to locate the points on either side of the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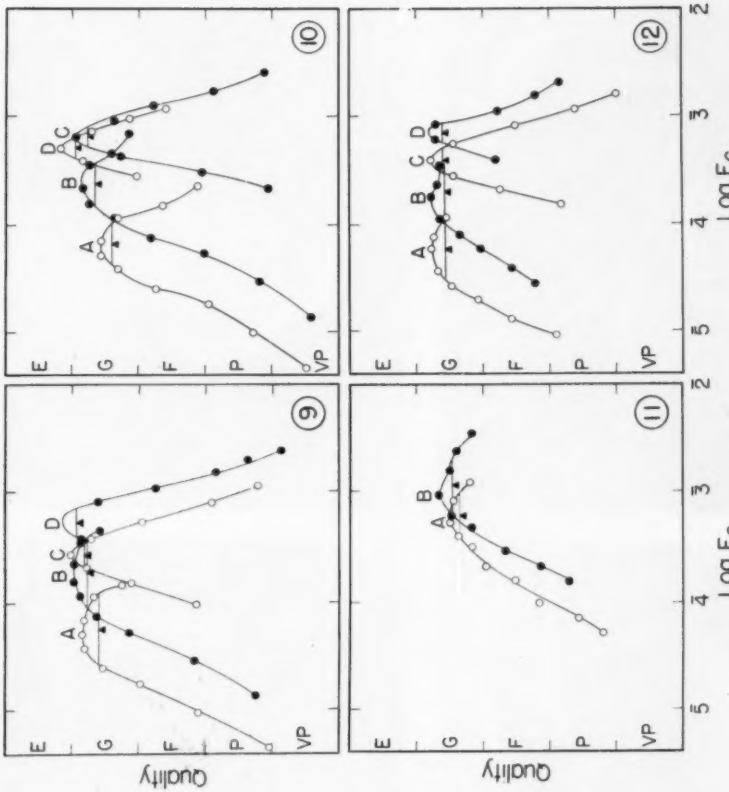

Fig. 5. Scenes 9–12 and respective curves of tone-reproduction quality as a function of the logarithm of camera exposure.

peak of each curve which fall at a given percentage of the maximum quality level for that curve. Of these alternatives, the second seems to be preferable for two reasons. If a high, fixed quality is used, it will be found that the peaks of the curves for some of the materials lie below this level, from which fact one might draw the incorrect conclusion that values of speed and exposure latitude cannot be determined for those materials. The second reason is that the potential maximum quality which can be obtained in any given case should not be ignored, as it would be if any fixed quality level were used, since, in fact, the attainment of this maximum quality is the desired objective for which any exposure recommendations which can be deduced from these curves will be used.

For the purpose of comparing the speeds of the four materials used in these tests, horizontal lines have been drawn at a level equal to 95% of the peak quality for each curve. The abscissas of the points at which these lines intersect each curve represent the smallest and largest values of log camera exposure which will yield this percentage of the maximum quality. The lengths of the lines between intersections represent the logarithms of the camera exposure latitudes. The camera exposure latitude is the ratio between the greatest and the least camera exposures which will produce the desired quality.

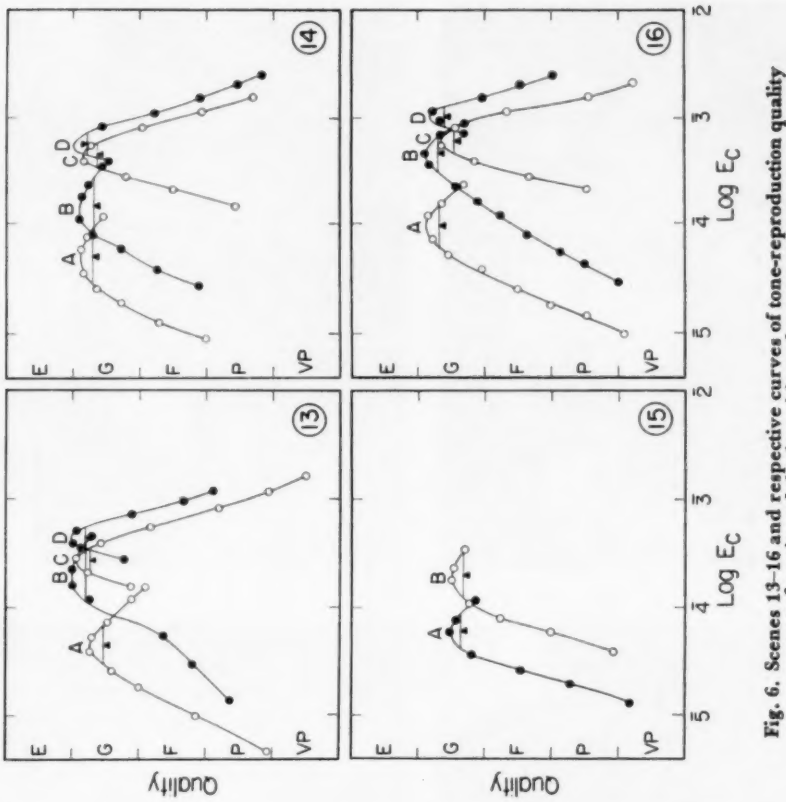

Fig. 6. Scenes 13–16 and respective curves of tone-reproduction quality as a function of the logarithm of camera exposure.

The logarithmic values measured from the curves for each scene are presented in Table I.

It has been stated earlier in this paper that the speed of a motion-picture negative film is inversely proportional to the minimum camera exposure required to produce a negative from which a positive print can be obtained that will give a projected screen image of high quality. For a given scene, then, the relative speeds of the materials are proportional to the camera exposures represented by the lefthand intersections of the horizontal lines at the 95% level with the respective curves. For any two materials the difference between the log E_e values for these points represents the logarithm of the ratios of the speeds of the two materials. The average ratio of the speeds of the materials can be determined from the average difference between the log camera exposures for these points for all the scenes studied. These differences are tabulated and the averages shown in Table II.

The curves of quality *vs.* log camera exposure presented here cannot be used to determine absolute speeds. A discussion of methods for deriving speed values is outside the scope of the present report.

The difference between *speed* and *exposure index* should be emphasized at this point. The speed of a photographic material is related to the *least* exposure which can be given to obtain a final

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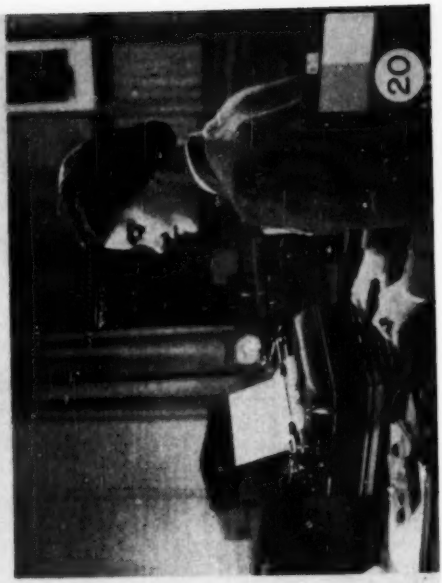
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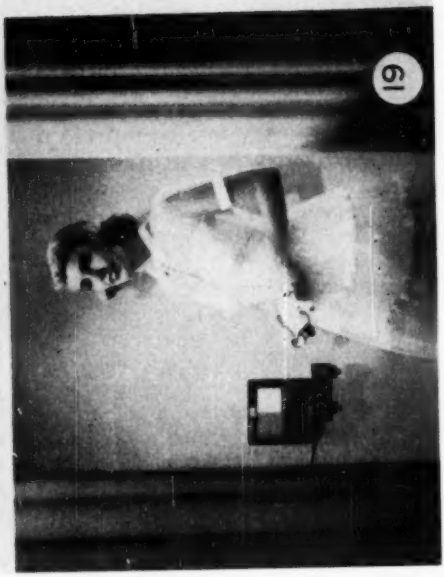
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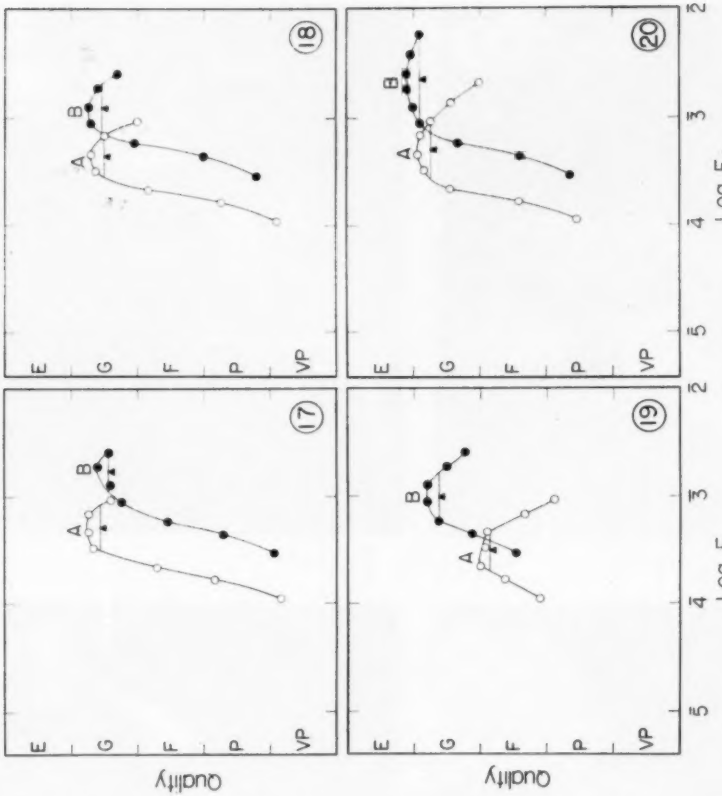

Fig. 7. Scenes 17–20 and respective curves of tone-reproduction quality as a function of the logarithm of camera exposure.

quality of a desired level. The exposure index, on the other hand, is related to the exposure which can safely be recommended in practice to produce final quality of the desired level. If an exposure index is used which results in the same camera exposure as that which is indicated on the curves of quality *vs.* log E_e by the speed point, then an error by the photographer in determining what camera exposure to use may result in his giving an exposure which is less than that required for a final result of high quality. The photographer using an exposure index in practice should find that he has a margin for error in the underexposure direction. The camera exposure latitudes which are tabulated in Table I show that there is a range of about $1\frac{2}{3}$ camera stops for Background-X Film, over which, on the average, at least 95% of the maximum attainable quality will be reached. For Plus-X Film, this range is, on the average, about $1\frac{1}{3}$ camera stops.

The exposure recommendations, i.e., the exposure index, which the photographer will use should be such that his results will, on the average, lie in the 95 to 100% maximum quality, Q_{max}, region. If it can safely be assumed that most of the photographers who use the exposure recommendations will be equipped to measure the illumination on their scenes and make necessary settings of shutters

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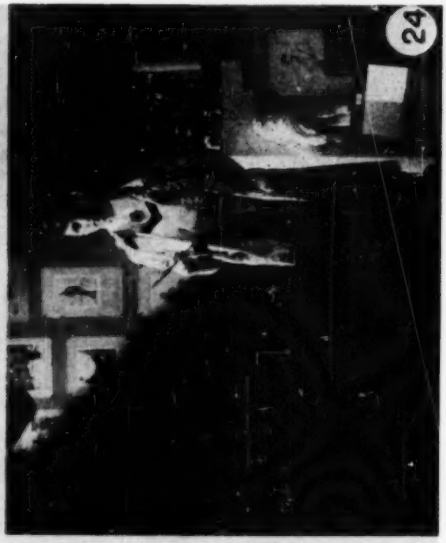
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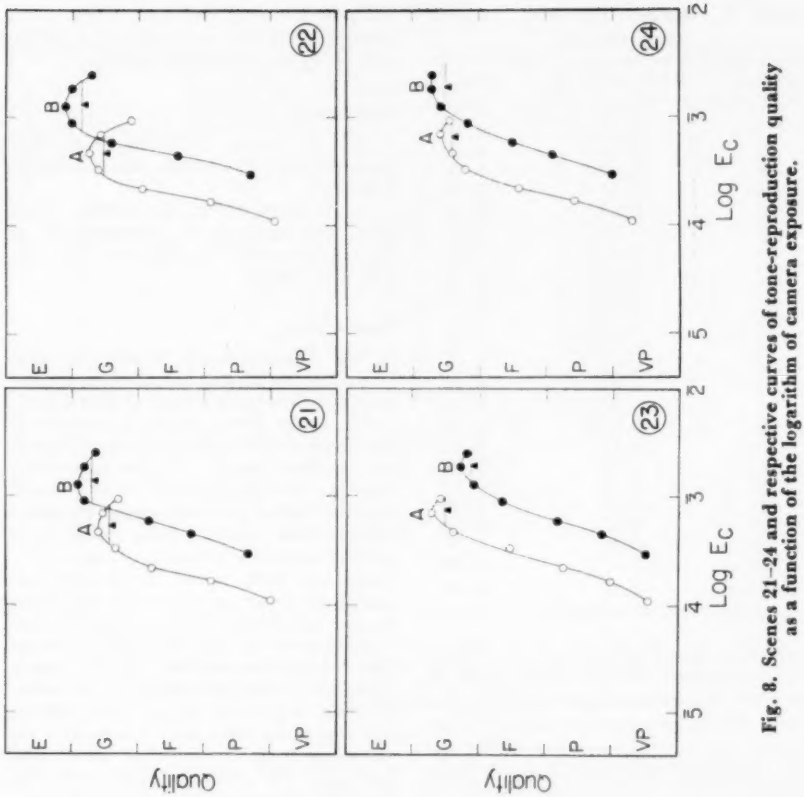

Fig. 8. Scenes 21–24 and respective curves of tone-reproduction quality as a function of the logarithm of camera exposure.

and lens apertures with a high degree of accuracy, then an exposure index can be assigned which is based on an exposure near the left end of the 95% Q_{max} line. The photographer can then use lenses of smaller aperture, shorter exposure times, or less light on his scene, all of which are factors that may be economically significant. In the present study, the midpoint of the 95% Q_{max} range has been selected as the point from which to determine relative exposure indexes. This has been done primarily for the purpose of illustration, and a final decision on this point will not be made until other studies are completed.

The differences between the logarithms of the camera exposures at the midpoints of the high-quality ranges are tabulated in Table III. The hypothetical curves for *X* and *Y* in Fig. 2 illustrate the fact that when the latitudes of materials being compared are different, the ratios between the speeds and the exposure indexes determined from the quality curves will, in general, be different.

Aside from the differences in latitude, there are no striking differences between the quality of the screen images which can be obtained from negatives on Background-X and those on Plus-X Film. There is some evidence that Background-X Film produces higher quality with scenes in which highlight and middletone details predominate or

Table I. Camera Exposure Latitude (Logarithmic).

Scene	Background-X	Plus-X
1	0.31	0.32
2	0.44	0.43
3	0.56	0.48
4	0.60	0.29
5	0.42	0.49
6	0.52	0.30
7	0.51	0.33
8	0.47	0.56
9	0.62	0.66
10	0.39	0.38
11	0.52	0.41
12	0.56	0.57
13	0.54	0.36
14	0.52	0.49
15	0.43	0.33
16	0.35	0.38
17	0.32	0.44
18	0.43	0.39
19	0.45	0.39
20	0.80	0.55
21	0.46	0.36
22	0.42	0.32
23	0.32	0.29
24	0.47	0.40
Average	0.48	0.41

represent important centers of interest in the scene. Plus-X Film seems to produce somewhat higher quality when there are large important shadow areas in the scene. The quality differences for individual scenes are small in most cases.

Summary

This investigation has shown that psychophysical techniques which relate subjective attributes to physical variables can be used to determine the variation in the quality of projected positive screen images from negatives which have received varying amounts of exposure. The results which have been obtained can be made the basis for a sensitometric speed and exposure index criterion for motion-picture negative films.

Acknowledgments

The author wishes to acknowledge many helpful suggestions from C. N. Nelson. F. T. Percy and his associates, William Cannan and Earl Kage, were responsible for the arrangement, lighting and photography of the scenes.

References

1. L. A. Jones, "Psychophysics and photography," *J. Opt. Soc. Am., 34:* 66–88, Feb. 1944.
2. L. A. Jones and H. R. Condit, "Sunlight and skylight as determinants of camera exposure," *J. Opt. Soc. Am., 38:* 132, Feb. 1948.

Discussion

Peter Krause (*Ansco*): Would you care to explain for us why an excellent quality rating was not given on any of the curves?

Mr. Sorem: Many of the judges placed the peaks of their individual curves high in the excellent region. At the same time, some of the judges were more critical, and they never gave any of the exposures an excellent rating. Also, although it may be surprising after seeing these curves, there was quite a lot of disagreement among the judges as to where the maximum quality points lay. Some judges like the highlights to be full of detail. Others like the shadows to be very excellently reproduced, and consequently the peaks of their individual curves were shifted one way or the other, and as a result when the values from the individual curves were averaged, the excellent judgments were pulled down considerably.

Mr. Krause: Would that not mean that perhaps the basis you have selected now for determining camera exposures is a little dangerous, because consumers might vary?

Mr. Sorem: That is one reason why we used more than thirty observers. We knew that thirty is about the minimum number which you can use safely to get an unbiased average from the group.

Mr. Krause: It has been my experience that people who judge their own pictures are much more critical and will judge them quite differently from people judging photographs with which they have no personal connection. In this particular instance, they were disinterested observers, were they not?

Mr. Sorem: That is correct.

Mr. Krause: Do you feel that there is a

Table II. Differences Between Logarithms of the Minimum Camera Exposures Producing High Quality.

Scene	Ektachrome Kodachrome	Kodachrome Background-X	Background-X Plus-X Outdoor scenes	Background-X Plus-X Indoor scenes
1	..	..	0.55	
2	..	0.55	0.39	
3	−0.09	0.66	0.53	
4	+0.03	0.71	0.35	
5	−0.05	0.65	0.54	
6	+0.21	0.48	0.49	
7	0.12	0.27	0.50	
8	0.33	0.37	0.52	
9	0.27	0.36	0.54	
10	−0.11	0.53	0.53	
11	..	..	0.20	
12	+0.29	0.46	0.52	
13	0.23	0.27	0.58	
14	0.11	0.64	0.44	
15	..	..	0.46	
16	0.26	0.19	0.69	
17				0.54
18				0.40
19				0.47
20				0.51
21				0.37
22				0.40
23				0.39
24				0.44
Average	0.13	0.47	0.49	0.44

Note: The differences in each column represent the minimum camera exposure producing 95% of the maximum quality for the first named material minus the minimum camera exposure producing 95% of the maximum quality for the second material.

difference between the judgment of an interested and disinterested person?

Mr. Sorem: I haven't considered the matter on that basis. I feel that one might expect a difference between the opinion of an expert and a nonexpert. However, we have found over a series of experiments that if you average the opinions of the experts and the nonexperts separately, and if each group is large enough, that the averages tend to be the same.

Mr. Krause: The curves seem to decrease on both sides of the correct exposure at about the same rate, so that if you were to include a safety factor against underexposure, would you not then run the risk that overexposure would also occur and would give a similar decreasing quality?

Mr. Sorem: Yes. That consideration, of course, points to the desirability of putting the recommended exposure at the midpoint.

Gordon A. Chambers (Eastman Kodak Co.): I'd like to comment on the first question. I happen to be one of those asked to be a judge. It must be kept in mind that the exposures covered were very wide in range, so that the first scene a judge saw was really pretty bad. As a judge you started in the dark — put a mark way down near the bottom of the chart for scene A; and then obviously as it began to get better, you started going up the scale, and you kept thinking, I've not yet reached the best possible print. As you were working up the page, and were finding prints in the good range, pretty soon they started getting worse. If you had been able to do it all over again you might have moved the whole curve up on the page. But I think that the number of people who had been accustomed to judging motion pictures were inclined to be on the conservative side when they

Table III. Differences Between the Logarithms of the Camera Exposures at the Midpoints of the High-Quality Ranges.

Scene	Ektachrome Kodachrome	Kodachrome Background-X	Background-X Plus-X Outdoor scenes	Background-X Plus-X Indoor scenes
1	..	..	0.54	
2	..	0.43	0.40	
3	−0.10	0.46	0.58	
4	+0.04	0.52	0.50	
5	−0.04	0.55	0.51	
6	+0.19	0.34	0.61	
7	0.16	0.11	0.59	
8	0.33	0.23	0.48	
9	0.29	0.16	0.51	
10	−0.10	0.44	0.55	
11	..	..	0.27	
12	+0.27	0.29	0.53	
13	0.21	0.10	0.68	
14	0.11	0.49	0.45	
15	..	..	0.51	
16	0.23	0.12	0.68	
17				0.51
18				0.44
19				0.50
20				0.64
21				0.41
22				0.46
23				0.47
24				0.48
Average	0.13	0.33	0.52	0.48

Note: The differences in each column represent the logarithm of the designated exposure for the first named material minus that for the second.

did this judging. They kept thinking, "the daisies in the next field are going to be better." So I think that the fact that the curves on the whole don't land up in the excellent range is a matter of human failing.

Mr. Sorem: I mentioned that the observers were given a preview of each series before being asked to record their judgments. We believe that allowing them to see the pictures twice minimized the effect described by Mr. Chambers. It is evident from the curves, that we did go about 1½ stops in the overexposure direction from what is ordinarily considered normal and 1½ stops in the underexposure direction. It was sometimes easier to go to underexposure than to overexposure. Also, in some cases, it was not possible to go that far in the overexposure direction, particularly for the indoor scenes, where there was the problem of getting sufficient light.

W. R. Holm (*Du Pont Photo Products Dept.*): You said that you were going to relate the exposures with the exposure meter readings, and I think this would be very interesting. Did you use a Macbeth Illuminometer both indoors and outdoors?

Mr. Sorem: We did.

Mr. Holm: Did you filter it outdoors, or did you use tungsten light?

Mr. Sorem: We used a filter.

Mr. Holm: Since this is a visual instrument, did you notice any differences between it and the others of the group?

Mr. Sorem: We have not proceeded far enough in our analysis of the exposure meter readings to determine that. I imagine we may find some differences.

Mr. Holm: What kind of filtering did you use with the Macbeth Illuminometer?

Mr. Sorem: We used a filter for the daylight scenes which produced a color match between the images of neutral areas in the scene and the comparison field in the instrument.

New 35mm Television Film Scanner

By E. H. TRAUB

New solutions for the film transmission problem for both black-and-white and color are described, comprising (1) nonstorage flying-spot scanning technique, (2) continuous exposure and (3) continuous film motion combined with optical compensation. A new form of optical compensator is then discussed which is both simple and small and which provides the possibility of solutions for film-shrinkage correction and iso-film-transport. The new optical compensator is corrected for various aberrations and has good optical efficiency. A color television film scanner incorporating these features is described.

OVER THREE YEARS AGO the Philco Research Division started a program of development leading toward the construction of a film scanner, to provide a source of color television signals. Originally planned as a research aid in the development of color television systems and color home receivers, the new Philco Television Film Scanner provides unequalled quality of reproduction from both black-and-white and color motion-picture film.

Background

At the very outset of this development program, it was recognized that existing black-and-white film transmission techniques were far from satisfactory in quality, and that the adaptation of these existing techniques to color television would result in still further deterioration of picture quality combined with unwarranted and excessive complexity of the apparatus.

The type of apparatus generally in use at present comprises a film projector converted to 3:2 ratio intermittent operation used in conjunction with means for providing pulse-exposure of light projected onto a storage scanning tube. The unsatisfactory film reproduction in black-and-white resulting from this combination has long plagued equipment manufacturers, broadcasters and the television audience. For color television operation along these lines, three storage scanning tubes instead of one would have to be used, requiring mutually precise registration, both electronically and optically. The attendant complexities arising from this triplication require no emphasis.

The Problem

Evaluation of these factors led to the conclusion that existing techniques must be regarded as obsolete. A completely fresh approach to the film transmission problem would have to be made which, in terms of picture quality, would give results equal or superior to those of a studio camera and which would be capable of excellent color performance without adding undue complexities to the apparatus.

It was decided that the existing concepts, involving (1) storage scanning

Presented on October 7, 1953, at the Society's Convention at New York by E. H. Traub, Research Div., Philco Corp., Philadelphia 34, Pa.
(This paper was received Nov. 30, 1953.)

tube, as typified by the iconoscope, (2) pulse-exposure and (3) intermittent film motion, would have to be abandoned entirely and replaced by the new, diametrically opposite concepts of (1) nonstorage (flying-spot) scanning tube, (2) continuous exposure and (3) continuous film motion combined with optical compensation.

This in turn would mean that the direction of the light-path would be completely reversed. The important implication of this change is that triplication of the scanning tube would become quite unnecessary for color operation. This would entirely avoid the triple registration problem previously referred to and would represent a tremendous simplification.

Such a system would provide the ideal in television film reproduction.

The Solution

In attempting to translate these fresh concepts into practice, Philco was in the fortunate position of being able to draw on a rich experience in nonstorage (flying-spot) scanning techniques, as exemplified by its "Flying-Spot Scanner" for opaque and transparent slides, already in use in numerous laboratories and television stations.

The practical realization of the remaining two features of the "ideal" system, namely continuous exposure and continuous film motion, were dependent on discovering a suitable optical compensator. This, then, proves to be the key to the whole system.

Much time, effort, and money had been spent over the past fifty years by organizations, both here and abroad, to develop such a device but without much practical success. Previous optical compensators were all too inefficient, too complicated or optically imperfect in operation.

It is actually not too obvious that the same optical compensating device which is required for the projection of continuously moving film onto a screen is precisely the same device which is required in order to project a television raster from a flying-spot scanning tube onto a continuously moving film. The following explanation may help to clarify these two relationships.

In the first mentioned case the function of the optical compensator is to *immobilize* the film on the screen, whereas in the second case the function of the same optical compensator is to *chase* the film with an image of the raster. Thus we find in comparing projection of continuously moving film with flying-spot scanning of continuously moving film that the same optical system is used in both cases, except that the *directions* of the light-paths are reversed and the concept of immobilization is also reversed and becomes "chasing."

Technical literature abounds with hundreds of schemes for optical compensation, most of which, incidentally, do not work. Generally speaking, optical compensators fall under three general headings: (1) rotating and/or oscillating mirror devices; (2) rotating lens devices; and (3) rotating prism devices.

Mirror Methods. The classical example of a mirror type of optical compensator is represented by the Mechau projector which was designed and built in Germany in the 1920's. It is important because it was the first technically successful continuous projector the world had ever seen. In spite of their relatively large size and complexity many hundreds of these projectors were built and sold, and until very recently their performance was not surpassed by any other similar device. Those of us who are working today in the field of optical compensation in relation to television cannot but have the greatest respect for the genius of Emil Mechau who is now revealed to us as being one of those rare men who in his technical conceptions was literally decades ahead of his time. Great credit must also go to F. Schröter who in the

mid-30's for the first time defined clearly in a theoretical paper the interrelationship between the continuous film projector (proper) and the television film scanner using optical compensation.

Lens Methods. Generally speaking, lens methods of compensation have been less successful than mirror or other methods for a variety of reasons. The optical aperture of such systems is usually somewhat limited by aberration considerations and the problem of identity of a large number of lens elements is and remains a serious one. Moreover, there are the problems of precision adjustment of the lenses and of cost.

Prism Methods. These are generally polygonal derivatives of the plane-parallel glass-plate type of optical compensator. They are based on the physical-optical phenomenon that a ray passing through a parallel plate of finite thickness will be displaced proportionally to the angular rotation of such a parallel plate, at least for a reasonable number of degrees of rotation, beyond which, however, the law of operation may be said to break down and the displacement becomes nonlinear. The well known optical designer H. Dennis Taylor, who will be remembered for his invention of the now famous triplet lens, was the first to publish a theoretical analysis of this type of compensator. The prismatic-polygon type of compensator has a number of features which make it highly attractive: It is simple, consisting essentially of a one-piece optical component whose precision can be "*built in*" once and for all. There are no adjustments either during assembly or during operation. Moreover, the device is both small and light, and can be manufactured at very reasonable cost. Until very recently, however, the theory of operation, and in particular the theory of prismatic aberrations, was not too fully understood, nor were the results obtained with these devices too encouraging. In the past few years, however, improvements of a very substantial nature have been made in the field of prismatic polygons, these improvements being based on a much better insight into the theory of operation and on a number of new inventions. It is the purpose of this paper to describe a new Television Film Scanner which uses such an improved prismatic-polygon type of optical compensator.

Description of Optical Compensator*

Space does not permit a detailed technical description of the reasons underlying the various improvements and changes that have been made to the prismatic-polygon system, but the following description will serve to convey the nature of the device as incorporated in the 35mm television film scanner presently in production.

The rotating element is shown in Fig. 1. Several distinguishing features are readily apparent. The polygon is 24-sided, rotating once per second. It has a diameter of about $5\frac{1}{2}$ in. The polygon is no longer a solid one, but has a large cylindrically polished hole cut in it. The polygon may be said to have sprocket teeth on it, or more correctly speaking the polygon is now so dimensioned that it can be fitted within the confines of a film sprocket. This permits the film to be partially wrapped around the polygon in such a manner that each film frame is optically and mechanically registered with each corresponding facet of the polygon. This is a most important feature of great practical significance. It is referred to as isotransport. In the absence of isotransport, when film velocity and polygon velocity are separately established, four dynamic conditions must be ful-

* An invention of Dr. John C. Kudar. Philco has the exclusive license under Dr. Kudar's applicable patents and applications, but only for the television field.

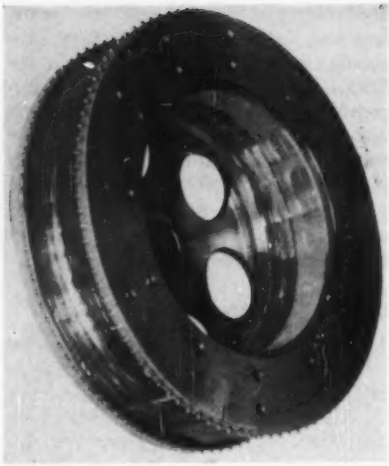

Fig. 1. 24-sided polygon and sprocket assembly.

filled in order to obtain compensation of film motion. These are:

(1) Uniform film velocity.
(2) Uniform polygon velocity.
(3) Synchronism between (1) and (2).
(4) Phase identity between (1) and (2).

Isotransport enables all four conditions to be fulfilled simultaneously and automatically, and in fact neither uniform film velocity nor uniform polygon velocity is any longer essential as long as both film and polygon rotate at the same speed.

Contained within the rotating polygon is a stationary optical system called a "core." This is shown in Fig. 2. It consists of a stationary platform which carries a number of optical elements essential to the functioning of the system. These elements are first, two plano-convex cylindrical lenses

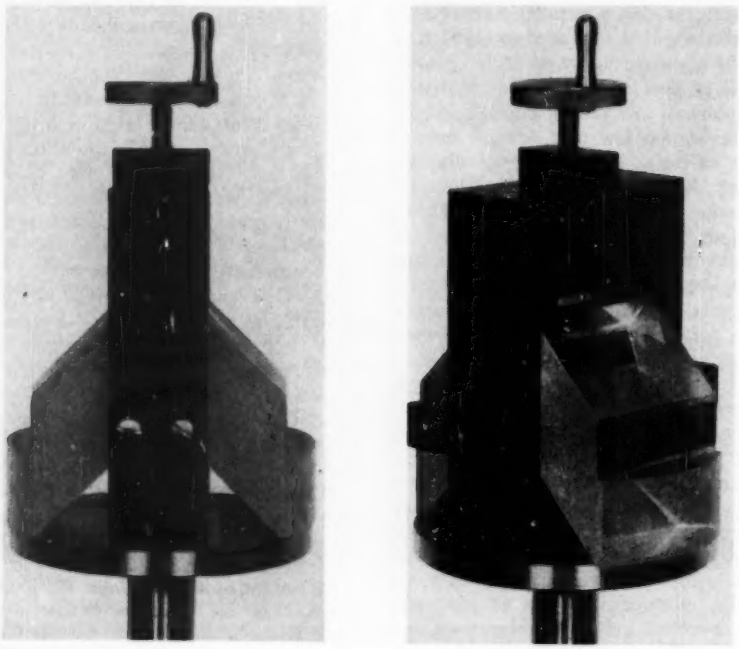

Fig. 2. "Core" assembly and shrinkage compensator.

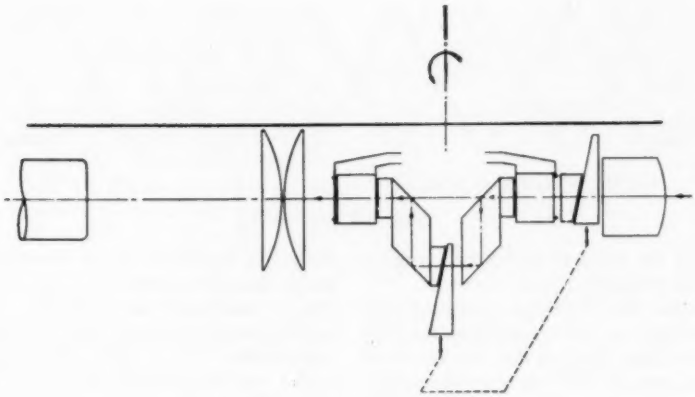

Fig. 3. 35mm optical system.

whose function is to form a zero-focus air gap between the rotating polygon and the other optical components which constitute the core. Second, there are two prismatic rhombs whose function is primarily to serve as path-length extenders in the optical sense. Without such path-length extension the diameter of the polygon could not be reduced sufficiently to enable it to be contained within the diameter of a film sprocket. Third, the core contains an adjustable optical shrinkage compensator the nature of which will be described later. Certain of the optical elements of the core are made of glass having a different dispersion from that of the polygon, which serves the further useful purpose of enabling the designer to correct the polygon for lateral chromatic aberration as a function of angular rotation. Other prismatic abberations, incidentally, can be readily controlled in design in a composite prismatic polygon of this type and can be kept within highly acceptable limits. Certain others, such as the spherical and longitudinal chromatic aberrations, can be corrected by means of a projection lens specifically designed to operate through the requisite glass path length.

A sectional view of the entire optical system is shown in Figure 3. The path-length extension created by the rhombic prisms is readily recognizable. The nature of the shrinkage compensator is also revealed.

It is an inherent feature of all machines using continuously moving film that their operation depends on the degree of shrinkage of the film. Therefore, in all such machines provision for shrinkage compensation of some kind must be made. In a prismatic-polygon type of optical compensator the best way to compensate for film shrinkage is effectively to vary the optical diameter of the polygon. This is, of course, quite impracticable in the case of the classical solid polygon, but is quite possible with the type of compensator here described. It is accomplished by introducing the optical equivalent of a parallel plate of variable thickness into the optical path between opposite pairs of facets of the polygon. The physical embodiment of this parallel plate of variable thickness is achieved by the subterfuge of sliding a thin wedge against a stationary wedge having a similar slope angle. The in-and-out movement of this wedge against its corresponding mate, separated by a very small air gap, then varies the optically effective path length

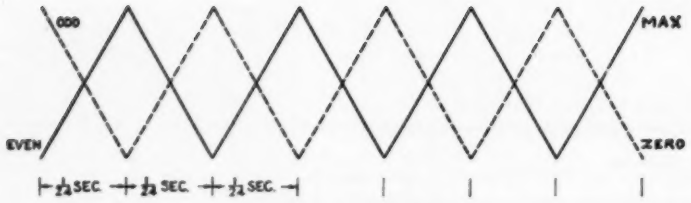

Fig. 4. Lap dissolve.

through the polygon and thus compensates for film shrinkage.

Optical film-shrinkage compensation of this type in turn introduces another complication which must not be overlooked, namely that varying the relative amounts of glass and air in the optical path between the projection lens and the film will in turn cause considerable defocusing of the image. Refocusing could of course, be accomplished by readjusting the projection lens, but this in turn would produce a slight change in magnification of the optical system. In order to avoid these difficulties, a second plane-parallel plate of variable thickness is introduced into the optical system between the projection lens and the polygon. This again consists of a stationary and moving wedge operating as an entity. This is called the "refocus compensator." The sum of the thicknesses of the shrinkage compensator and refocus compensator is kept constant by means of push-pull operation of the shrinkage-compensating wedge and refocus-compensating wedge respectively. This manner of operation then results in a shrinkage-compensating device of constant focus and constant image size irrespective of setting. In practice, the two wedges are ganged together and operated from a common control.

Methods of Picture Transition

In film devices of all kinds which use continuously moving film in conjunction with optical compensation, some specific method of picture transition from one film frame to the next must be used in the place of the intermittent pull-down which is employed in a conventional projector. Numerous methods of picture transition are possible. The method used in television film scanner described here is that called "lap dissolve" which can best be described as the alternate fading in and fading out of successive film frames. The light intensity from the odd- and even-numbered film frames is illustrated in Fig. 4, as this varies with time. For instance, while an odd-numbered film frame is fading from maximum to minimum light intensity on the screen, the successive even-numbered film frame is fading in from zero to maximum intensity. The important thing from the point of view of truly continuous and flicker-free operation is that the sum of the two light intensities should always add up to unity. Thus it will be seen that in lap dissolve, two successive film frames are always superimposed on the screen, except at one infinitely small moment when one film frame alone appears on the screen because the preceding frame has faded down to zero intensity and the succeeding frame has not yet had a chance to rise to a finite level of intensity.

The dynamic manner of operation is shown in Fig. 5 which relates the position of rotation of the polygon to the lap-dissolve diagram. The first view shows the polygon in the "normal" position, namely that which would be used if it were desired to transmit merely one stationary film frame (T_0). The second view shows the polygon in a position of rotation one-half frame-time later ($T_0 + 1/48$ sec). At this moment the light from the raster is seen to be evenly

divided between two successive film frames. The third view shows the polygon a small instant later yet ($T_0 + 1/24$ sec $+ \delta$). This moment in time in the rotation of the polygon is a particularly interesting one, as it clearly demonstrates that when precisely one facet is illuminated by the projection lens the chasing action of the optical compensator causes the raster to move potentially over a height of three film frames in extent; in other words, a "gate" three film frames high is required even though no more than two film frames are utilized simultaneously at any one moment.

The heart of the television film scanner, which is the optically compensated "picture head" or film-traction mechanism proper, is shown in Fig. 6. The ganged shrinkage control knob is easily recognizable as well as the polygon surrounding the stationary-core assembly and the refocus-compensator device. The mechanical simplicity of the picture head requires no emphasis, except to point out that the main large picture sprocket is not motor driven, but is driven by the film. Figure 6 also shows the relationship between picture head and the tri-color photocell housing. The special 4-in. flying-spot scanning tube is shown in Fig. 7. Its face is almost completely filled by a raster $2\frac{1}{2} \times 3$ in. in size which is of course a perfectly conventional 525-line, 60-field interlaced raster whose vertical and horizontal return traces are completely suppressed for the establishment of black level. The tube has a special fine-grain, short-persistence phosphor developed by the Lansdale Tube Company. It is operated at about 30 kv and at a beam current of 250 μa. The complete equipment is shown in Fig. 8.

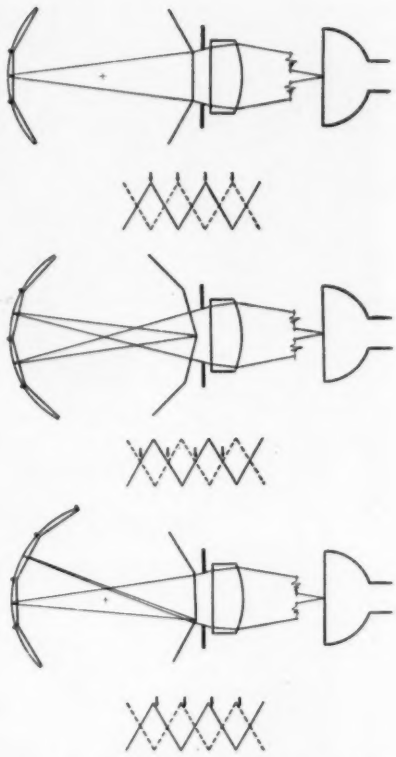

Fig. 5. Operational Diagrams: Position 1 (top); Position 2 (center); Position 3 (bottom).

Summary

The special features of the 35mm television film scanner may be summarized as follows:

(1) Continuous film motion, which has the advantage of greatly reducing film wear, implies a simpler and more reliable film-traction mechanism than is possible when operation is of the intermittent type.

(2) The optical compensator, which is a specially corrected type of rotating prismatic polygon, is a relatively small component revolving at a very low speed. This device has its own precision permanently "built into" it. Once manufactured it cannot change or distort in any manner, thus never requires further adjustment or maintenance.

(3) A film shrinkage correction device is provided as an integral part of

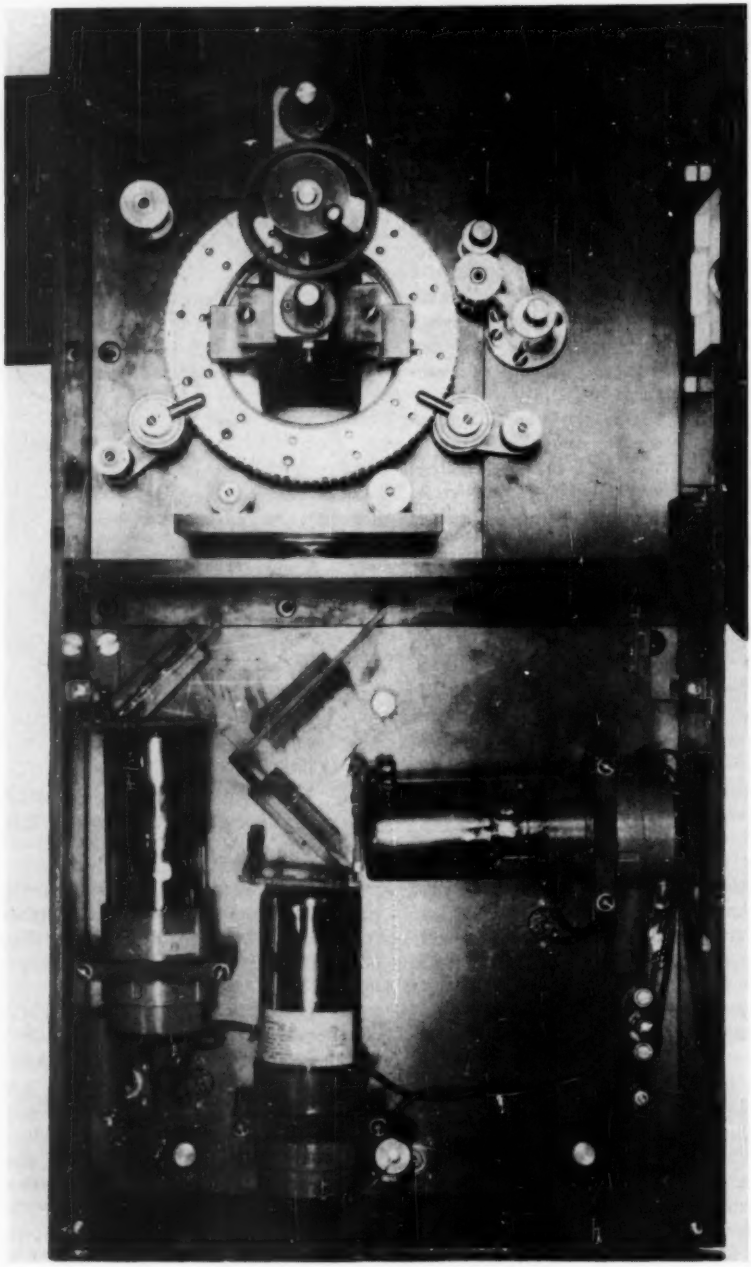

Fig. 6. Picture head mechanism and photocell housing

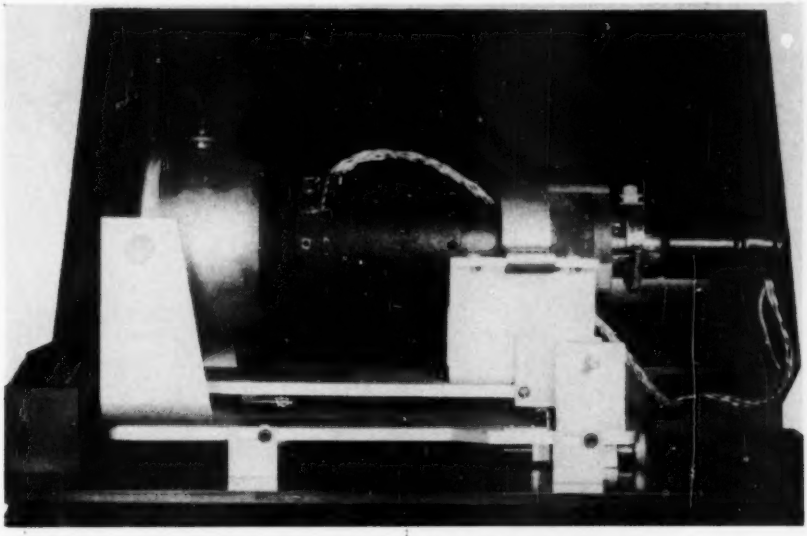

Fig. 7. Flying-spot scanner tube, with housing raised.

the optical compensator. This is preset at the beginning of a reel of film and thereafter requires no further attention.

(4) The exclusive isotransport feature is an inherent part of the television film scanner. This guarantees completely automatic registration between film motion and the optical compensator, always insuring their correct synchronism and phase relationship, regardless of film speed. It also avoids the necessity for vertical framing and provides pictures of extreme steadiness with freedom from flicker.

(5) Flying spot scanning is in itself a guarantee of the finest possible picture quality known to science today. It provides pictures of the finest resolution, superb half-tone reproduction, and a full range of contrast. The background level is automatically and accurately transmitted, and the picture is completely free from shading errors of any kind.

(6) This television film scanner is a *cold* scanner. The film cooling and burning problem does not exist, because of the complete absence of heat from projection lamps or arcs. The light on the film from the flying-spot scanning tube is absolutely cold.

(7) This television film scanner is a *universal* scanner.

(a) The scanner was designed from the outset for color operation but inherently also provides black-and-white pictures of excellent quality and complete freedom from noise. It gives color signals which can then be electronically repackaged to suit any of the several color television systems—simultaneous color, field-sequential color, line-sequential color or National Television System Committee compatible color system.

(b) The scanner operates at any film speed from zero upwards. Because of its cold operation, it is also possible to transmit stationary film frames, if desired.

(c) The scanner can simply and easily be converted to any existing foreign or domestic television standard, regardless of the number of lines or frames per second.

(d) The scanner is completely non-

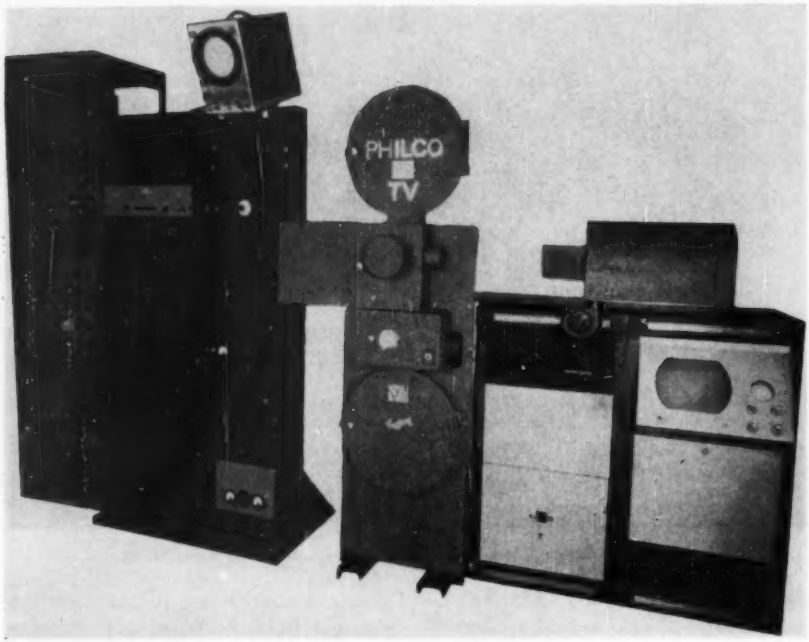

Fig. 8. Complete 35mm unit.

synchronous in operation, and with suitable power supplies can be used on any power-line frequencies. The non-synchronous feature is, of course of particular importance in connection with the NTSC color system. The rigid relationship required in present monochrome film transmission, namely the necessity for a line-driven synchronous motor for projector drive to achieve synchronism of film transport with deflection, has been removed. In compatible color television, where deflection frequencies are obtained by division from a crystal control master oscillator operating at the color-carrier frequency, the tremendous advantage of the non-synchronous method of operation of the television film scanner is obvious.

(8) Operational advantages of special interest:

(a) Short run-up time: this is practically instantaneous.

(b) The scanner can also be used as a caption or title scanner. It can, moreover, be readily multiplexed with a second picture head and, if desired, with a slide-transparency unit. It is here that the use of a stationary scanning raster is of special importance, as previewing between two picture heads or between film and slides becomes readily feasible.

(c) It offers the possibility of perfect timing of start of film programs or film inserts in live programs, by remote control if desired.

The film scanner here described is the 35 mm scanner now in production for several networks and research laboratories. A 16mm version is currently in an advance stage of development but it should be emphasized that it will differ in many technical details from the 35mm version, while preserving the essential features and advantages.

Fast-Cycling Intermittent for 16mm Film

By WARREN R. ISOM

A 16mm mechanism designed to advance the film during the vertical blanking time of the television system and its use with a flying-spot film scanner for color television is described. The order of the forces encountered is indicated. Also, solutions to certain auxiliary problems are given as well as operating characteristics and performance data.

FOR A LONG TIME, the need has been recognized for a film-handling machine that is capable of transporting the film from frame to frame within the vertical blanking time of the television system. Of the uses for such a machine, none is more important than that related to the problems of color television. The purpose of this paper is to describe a 16mm mechanism that advances the film in the vertical blanking time and to tell something of its use with a flying-spot scanner as a source of a video signal for color television.

Use in the System

The scanner is a flying-spot tube, RCA No. 73236-D, the raster of which is imaged by a $f/1.6$ objective lens upon the frame of film in the gate of the film transport (Fig. 1). This frame of film is held in the gate alternately for two and three scans, being advanced during the vertical blanking time. The light that is transmitted through the film is modulated by the photographic image upon the film. This modulated light is gathered up and directed by suitable condensers through selective reflecting and transmitting dichroics to the sensitive surfaces of electron multipliers, the red component to an RCA 6217 tube, the blue and the green each to an RCA 5819 tube. There is a preamplifier for each of these tubes, which work into channel amplifiers and other associated gear for the final processing of the original video signal to NTSC proposed standards. The preamplifiers as well as the servicing equipment for the flying-spot itself are a part, physically, of the film scanner unit. However, the scope of this paper does not include any further mention of this equipment. The principal concern here is the intermittent mechanism, shown in Figs. 2 and 3.

Presented on October 7, 1953, at the Society's Convention at New York by Warren R. Isom, Radio Corporation of America, RCA Victor Div., Engineering Products Dept., Camden, N.J.
(This paper was received October 9, 1953.)

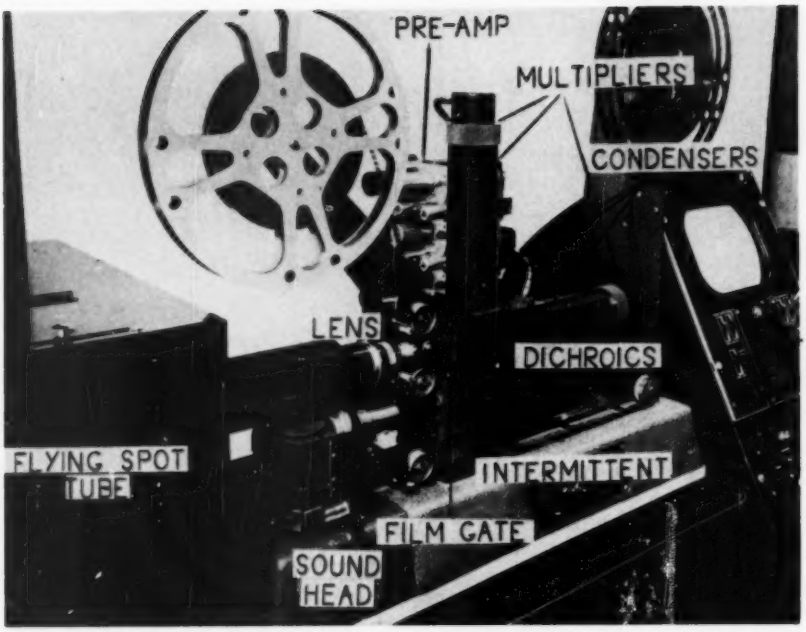

Fig. 1. The film scanner unit, embodying the fast-cycling intermittent.

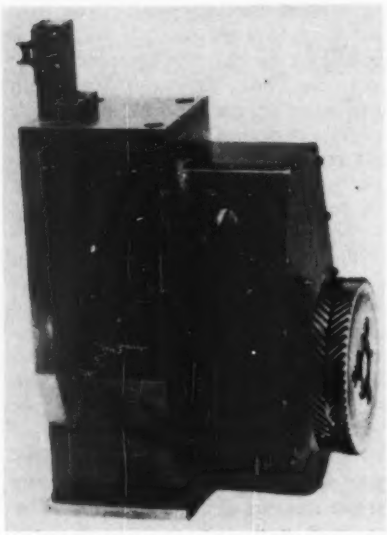

Fig. 2. The intermittent.

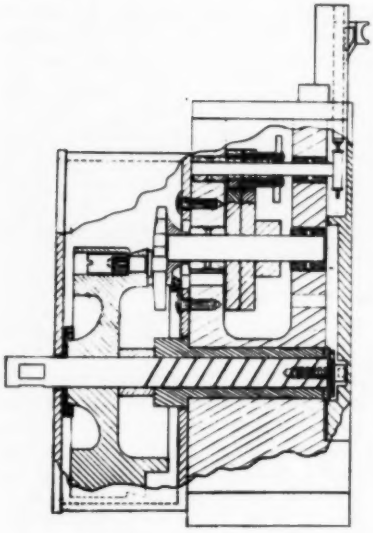

Fig. 3. Cross section of intermittent.

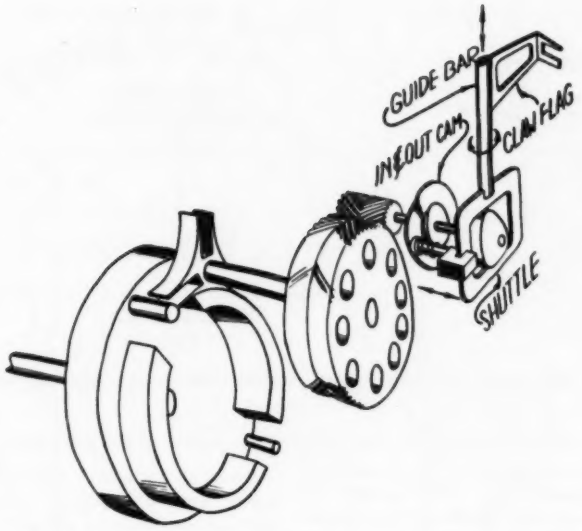

Fig. 4. Mechanical schematic of intermittent showing the Geneva and the shuttle-and-claw type intermittent coupled together with the herringbone gear train.

The Intermittent Mechanism

In essence, the mechanism is a three-pointed star Geneva coupled in series to a shuttle-and-claw type intermittent through a three-to-one step-up herringbone gear train. This can be seen from Fig. 4. The pinwheel and starwheel are of standard design taken from the Geneva used in the RCA TP-35 35mm Television Projector. The pins on the pinwheel are spaced 144° and 216° apart. Operating at 720 rpm, this spacing causes the cycling of the starwheel to be alternately at 20 and 30 cycles/sec. The weighted average of 20 and 30 is, of course, 24. This makes the cycling of the intermittent compatible with both the field rate of the television system and the frame rate of motion-picture film.

The entrance of a pin in the slot of the starwheel is the beginning of a cycle which results in a 120° rotation of the starwheel and, in turn, a 360° rotation of the camshaft. On the starwheel shaft is a nylon herringbone gear which drives a pinion one-third its size on the camshaft. Spur gearing was avoided in order to assure maximum tooth strength and the minimum tooth contact vibration. The herringbone gear was used instead of a helical gear in order to avoid end-thrust components from the intermittent loading of the gear train. Nylon was used because of the high ratio between shear strength and mass.

The camshaft carries both the in-and-out and the up-and-down cam. The up-and-down cam is a constant-diameter type fitted into a Scotch-yoke type of follower. This follower is a part of the shuttle for the claw. The guide bar for the shuttle serves as the connecting link between the claw flag and the follower. The point of attachment of the guide bar to the follower was selected so that the lateral components of the downward force are small. The in-and-out cam is a face-type cam.

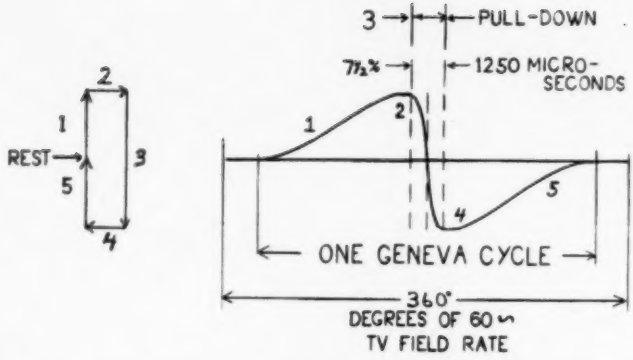

Fig. 5. Claw travel and Geneva cycle with displacement plotted against time.

The shuttle slides up and down in a slot in the spring-loaded follower and is positively controlled. This linkage of the in-and-out cam to the shuttle causes it to rotate in a plane at right angles to and about the guide bar. This action is communicated through the flag to the claw, causing it to move in and out of the film at the proper times.

Description of the Cycling

The 120° rotation of the starwheel each time the Geneva cycles is converted to a 360° rotation of the camshaft by the herringbone gear train. This brings about the following sequence of events: (1) the claw leaves its position of rest at the midpoint of its back stroke and rises to the top of its vertical travel; (2) it dwells there vertically while the in-and-out cam rotates the shuttle about the guide bar as a pivot until the flag moves the claw into the sprocket holes of the film; (3) at this instant the pulldown stroke takes place and the film is registered; (4) the bottom dwell is completed and the claw is extracted from the film; (5) the claw then returns to its position of rest at the midpoint of its back stroke, there to remain until the beginning of the next film advancing cycle (Fig. 5).

Calculations of the Pulldown Time

It is obvious that if a 110° up-and-down cam is coupled with a three-pointed star Geneva through a three-to-one gear train, pulldown time measured in terms of starwheel rotation is 36.67°. Also, if the effective ratio between the starwheel and the pinwheel is known, this time can be measured in terms of rotation of the 720 rpm or 12-cycle pinwheel. Five times this pinwheel rotation in degrees relates it to the 60-cycle field rate of the television system; 28.8° is 8% vertical blanking time.

These calculations can be made precise. The geometry of the three-pointed star Geneva (Fig. 6) is such that if the distance from the pin of the pinwheel at the time of its entrance in the starwheel slot to the center of the starwheel shaft is unity, then the radius of the pinwheel is 1.73205 and the distance from the center of the pinwheel to the center of the starwheel is 2. It is also known that the rotation of the starwheel necessary to produce the pulldown is divided equally about the midpoint of the starwheel cycle. It is seen from the above approximation that this rotation is 36.67°. Then one-half of the angle, or 18.33°, is the third thing known about the triangle formed by the lines joining the centerline of the shafts,

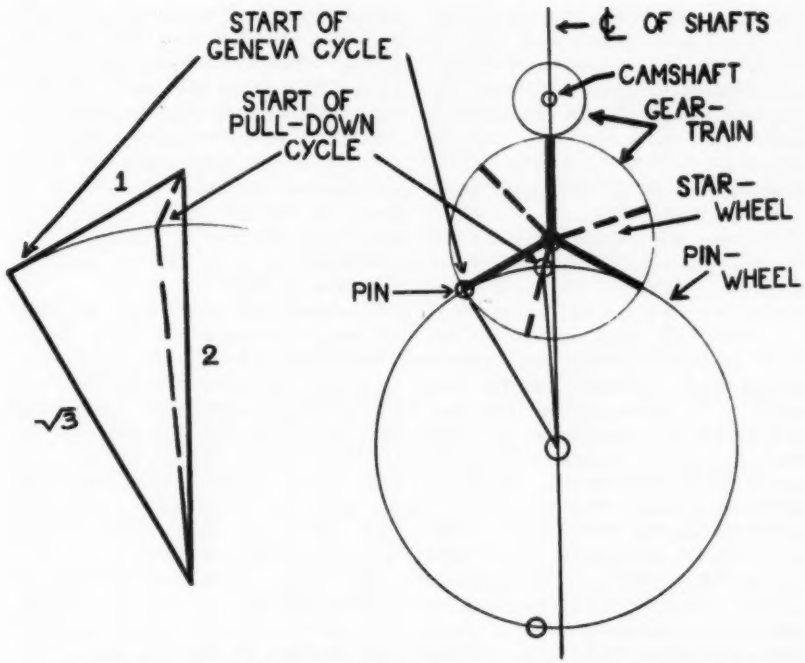

Fig. 6. The geometry of the system, showing general method of calculating the time of the pulldown stroke in terms of the rotation of the pinwheel.

the radius of the pinwheel at the beginning of the pulldown cycle, and the centerline between the pin and the starwheel shaft.

From the law of sines, the angle between the radius of the pinwheel and the centerline of the shafts is found to be 2.9650°. Twice this angle, or 5.93°, is the total time for the downward motion of the claw in terms of the rotation of the pinwheel. However, the claw is not in engagement with the film during this total time. One tooth of the claw is used as an indexing or registration pin. During the last half of the pulldown stroke, the film is allowed to overshoot the claw and be registered from the top of the sprocket hole against the uppermost side of the lower tooth.

If the intermittent is to accommodate film with 1% shrinkage, then the claw travel must be less than 300 mils. It can be only 297 mils. Otherwise, there is interference upon entrance of the claw in the sprocket holes of the next frame of film. Likewise, if there is to be no interference similarly when new film is used, the tooth that does the registering must be 3 mils less in vertical size than the sprocket hole. The vertical height of the registering tooth of the claw is 45 mils. This permits an entrance clearance of 1 mil between the top of the registering tooth and the top of sprocket hole when film with 1% shrinkage is used and 1 mil clearance between the bottom of the registering tooth and the bottom of the sprocket hole when 300-mil pitch film is used.

All of this means the claw will overtravel the film pitch from 1 to 4.5 mils. Commercial usage narrows this limit

to 1.5 to 4 mils. For this overtravel, the up-and-down cam rotates from 6 to 10°. Subtracting the pinwheel rotation needed to produce this overtravel, using the smaller figures, gives a net pulldown time in terms of the 60-cycle field rate of 27.727°. This is 7.7%. In the case of film with 1% shrinkage, it is 26.595° or 7.388%.

Timewise, this can be checked from another approach. The pinwheel revolves at 720 rpm. The peak ratio between the starwheel and the pinwheel is 6.4641. The peak speed of the starwheel is then 4,654.15 rpm which is approximately constant during the middle of the Geneva cycle. The gear ratio driving the camshaft is 3. This gives a peak speed of the cam of 13,962.46 rpm. This is 232.708 rps. Pulldown takes place during 105° of this rotation; and 360 divided by 105 is 3.42857. The reciprocal of the product of 3.42857 and 232.708, or 797.856, is the pulldown time in seconds. This is 1253.3 μsec, which is the maximum time required with new film. The 7.5% vertical blanking time is one-eight-hundredths of a second or 1250 μsec; 1333 μsec is 8%.

Calculations of the Forces Involved

Once the pulldown time is known, the question of the forces involved must be considered. First, the force that is required to accelerate the mass of the shuttle can be calculated by assuming that the up-and-down cam is rotating at constant speed during the pulldown cycle. Actually, the variation in speed during the 5° of action about the midpoint of the Geneva cycle is less than one-tenth of 1%. The time is one-eight-hundredths of a second. The motion of the claw is nearly uniformly accelerated. The weight of the shuttle is less than 5 g, or approximately 0.01 lb, and the displacement is 300 mils.

Substituting in the formula which relates displacement to one-half the acceleration multiplied by time squared, the acceleration is found to be 64,000 ft/sec/sec or 2,000 times that due to gravity. The simple harmonic motion equivalent for this is nearly 8,000,000 radians/sec/sec. Substituting values in the formula for the relationship between force, mass and acceleration, the force required to accelerate the shuttle is found to be 20 lb. This figure is significant because it establishes a relationship of 1 to 2000 between the mass and the force.

The mass of the film to be accelerated, 10 frames maximum, is 239.4 mg or 0.000529 lb, and the force required to accelerate this mass is 1.058 lb. The frictional load in the gate is in the order of 2 to 3 oz or something less than 0.2 lb. The total force on the sprocket holes of the film is approximately 20 oz, and the maximum acceleration force which the up-and-down cam is required to deliver is 21.25 lb.

The torque transmitted by the cam shaft to produce this force is 5.6 lb-in. This is reflected back on the starwheel and pinwheel through the gears. The force on the pin is 68 lb. This is the maximum force required to accelerate the shuttle and the film.

The force required to accelerate the rotating parts can be determined from the rotational inertia of the parts and from their rate of acceleration. The only interest is in maximum acceleration. For the starwheel, this is 2,963.2 radians/sec/sec. The rotational inertia of the starwheel driver gear assembly is 0.005 lb-in.; that of the camshaft assembly is 0.0005 lb-in. The total maximum torque required to accelerate these parts is 19.5 lb-in. To do this, a force of 80 lb must be delivered by the pin of the pinwheel.

Sequence of the Application of the Forces

There are essentially three types of forces involved in driving this intermittent: frictional, rotational accelerating, and the shuttle accelerating forces. The heaviest frictional load in

the drive is just as the pin enters the starwheel slot, because at that time the static friction of the parts must be overcome. Also at that point the velocity of the pin in the slot is maximum.

During the midrange of the Geneva cycle, the frictional load has diminished to a minimum. In fact, at the midpoint, so far as the drive is concerned, it drops to zero, for at the crossover from acceleration to deceleration there is no driving force. With this relaxation, contact pressures throughout the system are relieved.

This is also true to a lesser extent for an appreciable part of the cycle preceding and following the midpoint of the Geneva cycle. It is during this diminishing in the frictional load that the force to accelerate the rotating parts is applied. The peak acceleration for this purpose comes at 4° 46′ before the midpoint. This drops rapidly to zero for the variation in speed of the starwheel during 5° about the midpoint is one-tenth of a percent.

It is during this lull in the frictional and the rotational accelerating forces that the force to accelerate the shuttle is applied increasingly as the other two are simultaneously decreasing. Thus, the forces are staggered. It can be seen that this arrangement results in the minimization of forces, not the addition of forces, simply because one thing is done at a time, albeit in somewhat quick succession.

General Performance

After establishing the fact that the machine will operate, considerations of life are in order. The engineering models of this mechanism were based upon a Geneva that was designed and built for another service. A tribute to the adequacy of the design is its performance under loads that were not imagined during the design stage. However, its performance has given the assurance that a Geneva built for this specific duty will be completely reliable.

The operation of this mechanism can be likened to that of a high-gain amplifier. To avoid distortion, multiple stages are used. In this mechanical amplifier multiple stages are also used. The Geneva is the first stage, performing the function of a pulse former and preamplifier. The connecting gear train is a voltage amplifier and the up-and-down cam plays the part of the power-output stage.

This analogy is more significant than apparent. It points up how steep-pressure angles and attendant large concentrations of forces have been avoided. Besides that, it dramatizes the specific use of each part of the assembly. The Geneva is not used in the conventional manner. It is a pulse former. It plays no part in the final positioning of the film in the gate. It is also a speed multiplier. Since it has only a power function to perform, and since it is the first element in the system, opportunity is afforded to make it rugged enough to handle the job that has been cut out for it. It can be as massive as necessary for it operates at one-half normal speed. There is no high premium on low inertia in this stage. On the other hand, in the case of the gear train, there is a premium on low inertia and the choice of nylon is a happy one. For the up-and-down cam, only one last job remains — that of moving and positioning the film. Low mass in the shuttle is really important and the design has been left free of other functions so that small parts can be used.

Proper, if not first, regard has been given to the film. The practice of registering the film in the aperture by stopping it with friction in the gate against the propelling tooth is reversed. The film is allowed to overshoot the propelling claw and be registered from contact of the back side of the tooth against the top edge of the sprocket

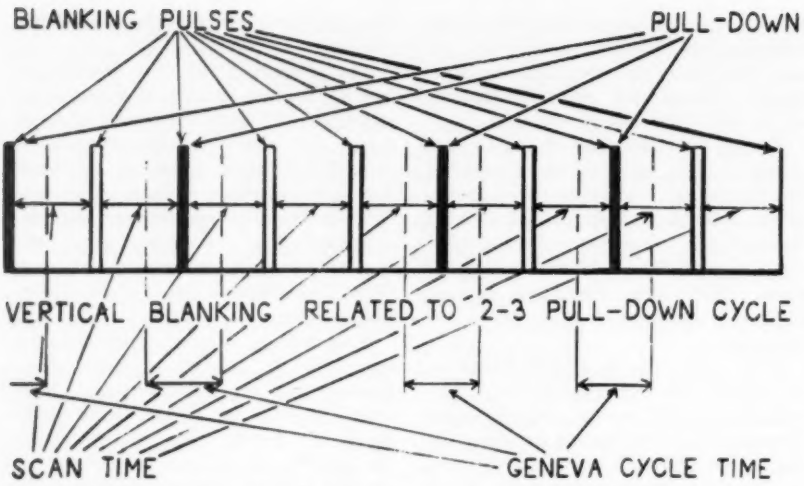

Fig. 7. The relation of the mechanical cycling to vertical blanking time.

hole. This has reduced the need for friction in the gate to that which is the result of edge-guiding and that which is necessary to insure mechanical stability. This is sufficient to prevent film from bounding back after registration. The deceleration of the claw is much greater than the free deceleration of the film. Consequently, the registering edge of the sprocket hole is in contact with the back side of the tooth long before the end of the pulldown.

Attention has also been given to film steadiness. The tooth that acts as a registration pin is solidly connected to the follower of the up-and-down cam. At the end of each stroke, the tooth figuratively sits on the same cam dwell and waits for the film to be registered against it. In the process, any unevenness of wear, or the build-up of tolerances, once-around variations, or the nonuniformity of parts plays no role. Using this method of registration means that the surface of the film is not subjected to any unusual pressures. It also means that in no case is the film in danger of damage from the claw, even when an improper loop is formed. The gate pressure is so light that the film frees itself before any damage can be done. The accelerating force of 20 oz on the film seems to be well within the operating range of forces permitted. The sprocket holes show no appreciable wear after a thousand passes. Perhaps the film, due to its plastic nature, braces itself against the quickness of this action. After all, such forces have long been encountered in film-handling equipment, particularly in the holdback sprockets against which rewind mechanisms work.

Operating noise is not an unimportant item. The operating noises of the engineering models has been little greater than that of other television film-handling equipment. However, when the mechanism is in place in its final design package, and is operating, it is hard to conceive from the resulting noise that there is a piece of film being accelerated and decelerated up to and down from 22 mph in a millisecond, 24 times a second.

General experience with units in the laboratories of RCA Victor Engineering Products Division in Camden and in

the experimental color program at NBC in New York indicates that it is both possible and practical to advance 16mm film during the vertical blanking time of the television system (Fig. 7). This approach to the film-handling problem for color television preserves maximum optical speed for use by the scanner. The ability to advance the film from frame to frame in this limit of time makes possible new techniques for many uses of film in television as well as in other motion-picture applications.

Acknowledgments

Many immediate associates contributed substantially to the development of this project. Special recognition must be given the support and the collaboration of J. J. Hoehn of the Commercial Sound Section and Arnold E. Jackson of the Television Terminal Equipment Section of the RCA Victor Manufacturing Co.

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The CinemaScope Optical System

By JAMES R. BENFORD

The CinemaScope system for the presentation of motion pictures in existent theaters has resulted from major technological advances along two facets of engineering: optics and sound reproduction. The optical aspect has given rise to the wide-screen picture. The sound reproduction aspect has yielded stereophonic sound. In the consideration of the subject the optics shall be considered the dominant factor although the sound, the screen, the film and the projection equipment are to be reviewed.

CINEMASCOPE is the name applied to the Twentieth Century-Fox wide-screen motion-picture process. The process achieves a picture twice as wide as the standard motion picture, using a single conventional camera and a single conventional motion-picture projector. The wide-angle panoramic picture is achieved by the use of cylindrical lens attachments to the camera and to the projector. The function of the cylindrical lens attachment on the camera is to compress a picture of twice the normal angular width onto a conventional 35mm film without altering the height of the picture. The cylindrical lens attachment on the projector expands this laterally compressed image, restoring it optically to a correctly proportioned picture but having twice the conventional picture width. Such a system, where the intermediate picture is distorted and then restored in the final image to a nondistorted picture, is called "anamorphic."

Presented on October 9, 1953, at the Society's Convention at New York by J. D. Hayes for the Author, James R. Benford, Bausch & Lomb Optical Co., Rochester 2, N.Y.
(This paper was received Nov. 9, 1953.)

The panoramic view which such an anamorphic system is capable of achieving greatly heightens the reality of the scene and increases the potential possibility of producing motion pictures for increased "audience participation." This possibility is further heightened by stereophonic sound which, by means of three separated sound amplifiers behind the screen, re-creates the direction of the sound, as it occurred in the original scene. To achieve the double-width projected image without loss of image brightness the Twentieth Century-Fox engineering staff has developed a specially embossed projection screen which, when formed into a gentle cylindrical curve, directionally reflects the light into the useful theater area, rather than allowing it to scatter at random throughout the theater.

The CinemaScope process may thus be characterized as including three major items: (1) The anamorphic compression and expansion lens attachments; (2) the stereophonic sound; and (3) the improved directional projection screen.

Historically the use of cylinder lenses to achieve wider angular coverage on film goes back to the latter part of the

19th century.[1] The general application of this idea to motion pictures was patented in this country in 1912 by Ernesto Zollinger of Turin, Italy. The problem of producing well-corrected lens designs along this line received the attention of H. S. Newcomer, of New York City, and several patents were issued to him in the period between 1930 and 1940.[2] In this same period H. Chrétien of St. Cloud, France, also produced finished anamorphic lens designs using cylindrical lens systems[3] for use as attachments for motion-picture camera and projection lenses. One of Chrétien's designs was used as a basis for the design now being produced by the Bausch & Lomb Optical Co. for the CinemaScope process.

The Chrétien design was submitted by Twentieth Century-Fox to Bausch & Lomb early this year, with the request that immediate quantity production be started. The conversion of the design to modern types of optical glass and the establishment of manufacturing tolerances and inspection standards were immediately started. At the same time, experimental equipment was obtained, and experimental lenses were produced on this equipment, in order to determine the techniques needed to mass produce accurately aligned and optically precise cylindrical lens systems. A very tight engineering and manufacturing schedule was necessitated by the pressure for production of a number of CinemaScope motion pictures in a very short time, and this schedule was met and bettered. In the early weeks of this year a number of lenses were completed and put to immediate use, and since then continuous production has kept pace with the rapidly expanding demand for these lenses.

Figure 1 shows the path of light through the anamorphic camera attachment. The top view shows how the cylindrical lens system acts like a reversed Galilean telescope in the horizontal meridian, effectively halving the focal length of the objective and doubling the field coverage. In the vertical meridian, however, the anamorphic attachment leaves the focal length and field coverage unchanged, as the cylindrical system has no lens power in this meridian. It will be evident that the anamorphic lens system must form an image in the same plane as the object, i.e., must be afocal, in order that both horizontal and vertical fans of rays shall come to a common focus, so that the system shall be free from astigmatism. To maintain this afocal property at all object distances, it is necessary to provide a focusing motion of the negative lens with respect to the positive lens. The maintenance of precise alignment of the cylinder lens axes during this focusing motion is probably the principal mechanical feature differing from conventional focusing mounts. Very precisely fitted double keyways have provided the means for maintaining this alignment.

The anamorphic projection attachments are very similar in basic form to the camera attachment, differing mainly in the relative size of the positive and negative lenses. This is simply to conform to the larger aperture but smaller angular field coverage required in projection. The projection attachments are shown in Fig. 2. The smaller form is designed to work in conjunction with the new 3-in. to 5-in. $f/1.8$ Super Cinephor projection lenses. The larger

1. Cf. British Patent No. 1453, May 14, 1862, by Leon Farrenc.

2. British Patent 349,507, May 26, 1931; U. S. Patent 1,932,082, October 24, 1933; U. S. Patent 1,945,950, February 6, 1934; U. S. Patent 1,945,951, February 6, 1934; U. S. Patent 2,207,409, July 9, 1940.

3. British Patent 356,955, September 17, 1931; U.S. Patent 1,829,633, October 27, 1931; U.S. Patent 1,962,892, June 12, 1934; U.S. Patent 1,829,634, October 27, 1931.

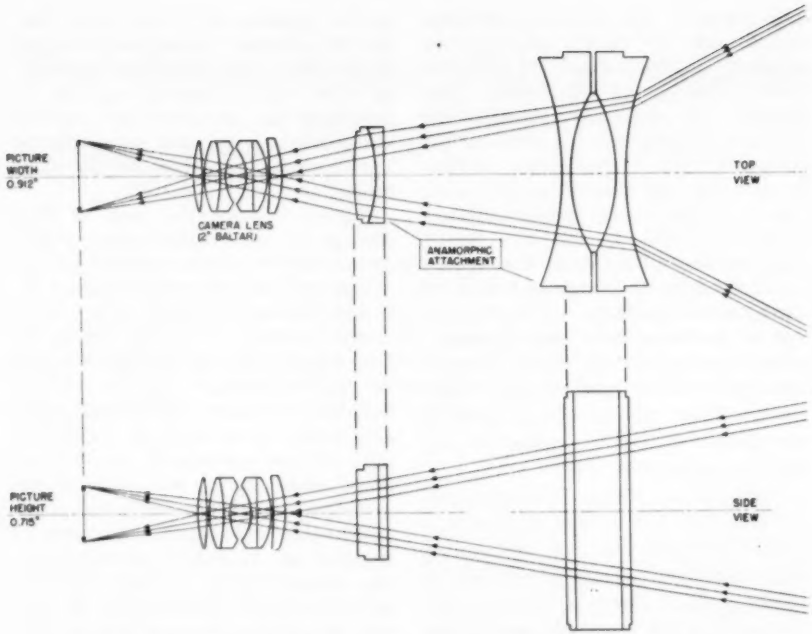


Fig. 1. The path of light through the CinemaScope camera attachment.

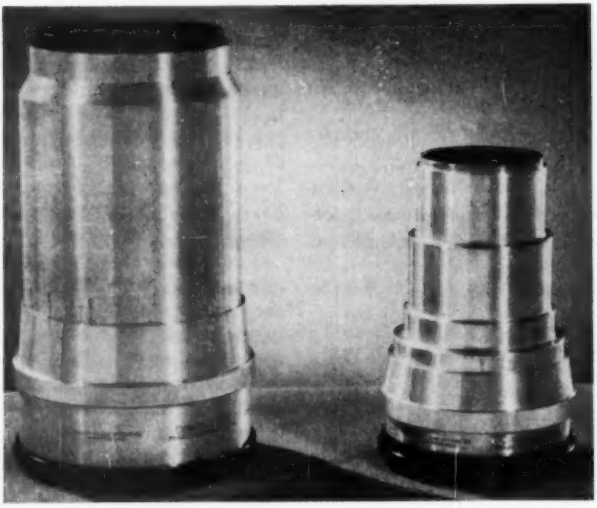


Fig. 2. The Bausch & Lomb anamorphic projection attachments for CinemaScope.

form is designed for the focal lengths over 5 in. The anamorphic attachments are provided with a focusing mechanism with a graduated footage scale, and a locking mechanism to maintain the focus at the proper projection throw. This focusing is done only once and the unit then locked at this setting. The projection lens itself is then focused to give maximum sharpness in the normal manner.

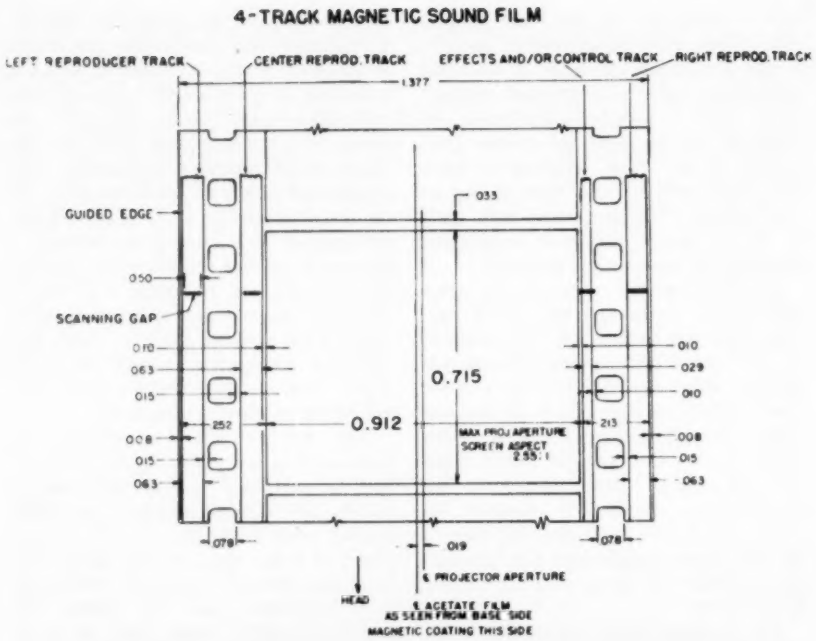
By reason of the conversion to magnetic sound tracks and the use of narrower sprocket holes it has been possible to start with a larger original frame size thereby reducing graininess to a minimum. The CinemaScope vs. the regular frame sizes are shown in Fig. 3. Both height and width of the frame have been increased. After projection the CinemaScope picture is doubled in width, so that the comparative sizes of the final projected standard and CinemaScope picture are as shown in the bottom of the figure.

The location of the sound tracks and the narrowing of the sprocket holes for the CinemaScope film are also shown in Fig. 3. The sprocket holes are located toward the outside limit of their position on standard film, so that after the sprockets in the projector have been narrowed down CinemaScope or regular film can be interchangeably projected. The narrower sprocket holes not only result in more available picture area, but also strengthen the film against wear. Figure 3 shows how much more of the film area is being used in the new process.

Figure 4 shows the relative simplicity of converting a standard motion-picture projector from conventional to CinemaScope pictures. It should be emphasized that this simplicity of conversion and the fact that only a single standard 35mm projector is used, greatly adds to the economic feasibility of the process. In Fig. 4, A represents the magnetic soundhead which is fastened permanently in place between the upper magazine and the top of the projector casting; B represents the anamorphic projection attachment which is mounted in such a fashion as to be easily removable for projecting conventional pictures. In projecting conventional pictures the magnetic soundhead is by-passed. The single-track optical soundhead is in use in this arrangement. In CinemaScope presentation the optical soundhead is by-passed, and the film threaded through the stereophonic magnetic soundhead. The three major magnetic tracks amplify respectively through the left, center and right sound amplifiers located behind the screen, and re-create the direction from which the original sound came.

The special screen developed by Twentieth Century-Fox engineering staff has an embossed surface designed to direct the reflected light into the useful seating area of the theater. It is composed of many tiny concave mirror-like elements which by reason of their relative curvature and size reflect the parallel incident beam back as a divergent beam of controlled angular extent in both horizontal and vertical meridians. Two patterns are available, a head-on pattern and a tilted pattern, the type selected being dependent on the theater construction and on whether the screen itself is tilted or vertical. A 2:1 gain in image brightness is realized with this screen.

In conclusion, it would be well to analyze the basic reasons for using anamorphic lenses in preference to conventional spherical lenses. There appear to be two basic reasons for the use of the anamorphic lenses. The first is to enable one to keep graininess to a minimum by use of the maximum useful film area, in a process where for practical considerations this can best be achieved by different aspect ratios at intermediate stages in the process. In this respect the CinemaScope process might eventually be improved by the use of a larger initial picture which can be reduced in printing to the existent



CinemaScope frame size, since most of the practical limitations on film size occur in projection, rather than in photography. The second basic reason for the use of cylindrical anamorphic lenses lies in lens design simplifications, due to the fact that a cylindrical-lens system need be corrected only for the tangential focus, since it has no lens power for the sagittal fans of rays. This simplifies the field flattening in the cylinder-lens system, since it assures the lens design the same degree of correction for curvature and for astigmatism. For this reason the cylinder system can give better field correction than the conventional spherical-lens system for the same degree of complexity of the lens system.

The CinemaScope process may therefore be summarized as a practical single-camera, single-projector process, utiliz-

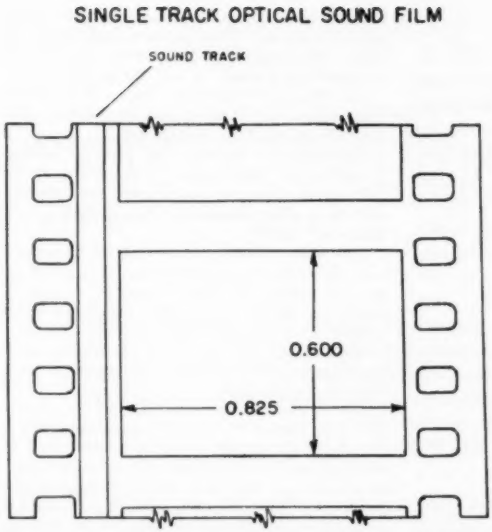


Fig. 3. Comparative size of CinemaScope and conventional frame, and comparative size of final projected image.

ing cylindrical anamorphic-lens attachments for both camera and projector, to produce a picture of twice the normal width taking fullest advantage of the available film area on standard 35mm film, combined with a curved panoramic screen with controlled reflectance to maintain optimum screen brightness, and with magnetic stereophonic sound to heighten the sensation of reality in the scene.

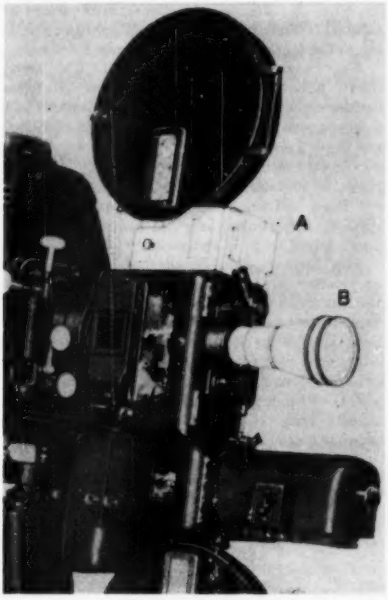


Fig. 4. Conversion from conventional projection to CinemaScope projection by the addition of the magnetic stereophonic soundhead A and the anamorphic projection-lens attachment B. (Photo Courtesy Twentieth Century-Fox.)

Acknowledgment

Messrs. E. I. Sponable and H. E. Bragg of Twentieth Century-Fox have supervised the engineering and development of the CinemaScope process in its entirety. At Bausch & Lomb the engineering and development of the lens systems has been carried out under the supervision of Dr. Howard S. Coleman. Engineering tolerances and inspection specifications have been the responsibility of A. E. Neumer. Lens design work has been carried out by Dr. N. A. Finkelstein and E. Delano. Process development work was supervised by T. J. Zak and factory engineering by W. R. Knowlton. The mechanical design was carried out by O. W. Boughton and C. DeGrave.

Discussion

Chester E. Beachell (*National Film Board of Canada*): What is the change in focal length as the angle increases out to the side in the lens?

Mr. Hayes (*who read the paper*): It's pretty nearly linear as it works its way out. In other words, right dead center we have what we call a no-power system. In the vertical direction we have a so-called no-power system. As you go directly out in the horizontal direction, your power is increasing. As we go off on the bias, we have different degrees of power. To be specific, at so many degrees from the center I don't know what is the power.

Mr. Beachell: You stated that it was possible to produce an anamorphic lens with prisms as well as cylindrical lenses. I would think that this curve would be very critical in setting up some kind of standard. If a picture were taken with this cylindrical anamorphic lens and a prismatic lens used to reproduce it, or vice versa, would the picture appear in its original proportions? That is, would the cylindrical and prismatic optics be interchangeable?

Mr. Hayes: I haven't seen any pictures of this type made with prismatic lenses but I know that some have been made. A considerable amount of work has been done on the use of prismatic lenses. They have a slight taper to them. The same effect is achieved with the use of cylindrical surfaces, as with the prisms.

Mr. Hayes: I think that they will be interchangeable, but I can't say for certain. We haven't computed the two systems.

Ben Schlanger (*Architect, New York*): I wonder if there's any information on the origin of the 2.55 aspect ratio and also is there any information as to what Chretien's original feeling was about that ratio?

Mr. Hayes: There is in one of Chretien's early patents relating to the use of anamorphic lenses a discussion of the format size. I don't recall his conclusions, but they should be in his patents in the late twenties or the early thirties.

Mr. Schlanger: What is the up-to-date basis for the selected aspect ratio, at least as CinemaScope has adapted it?

Earl I. Sponable (*Twentieth Century-Fox Corp.*): When we started to make CinemaScope pictures we placed the picture on the available width of the film and we came out with an aspect ratio of 2.66:1. At that time we made experiments going from 2.66 on down through 2.0 and 1.8 and 1.5. The people at our studio decided they liked the wide picture, the widest picture we could make. When we came along and put the sound tracks on we had to use some of the picture area, so we ended up with 2.55:1. That's how we arrived at that figure.

Denis Gillson (*National Film Board of Canada*): Are the depth-of-field characteristics of the taking lens adversely affected by the use of the anamorphic lens?

Mr. Hayes: In theory, no; in practice, it has been found that instead of using the standard focusing position, a better compromise can be found.

Mr. Sponable: I'd like to give a practical answer in that the depth of field is increased by the use of the anamorphic lens. We have some recent pictures made in Venice in which the depth of focus is simply amazing. It seems to go on, and on, and on. I think that theoretically it's increased about twice, isn't that right, Mr. Hayes?

Mr. Hayes: Somewhat. It's increased in the horizontal direction by virtue of the short focal length. You would get a peculiar ellipsoid if you tried to plot the depth of focus in the two directions.

Stereophonic Tape Recording Equipment

By RUSSELL J. TINKHAM

Electrical phasing, time phasing and balanced loudness between channels are necessary for the maximum realization of the benefits of a stereophonic recording system. Elements and characteristics of two- and three-track recording and reproducing systems are briefly described.

Ampex began the commercial production of multitrack tape recorders about four years ago for those interested in recording telemetered information from guided missiles and the like. These equipments provide any number of simultaneous channels up to 14. It was a simple step, therefore, to make stereophonic tape recorders with two or more channels.

After reviewing the literature, and our prospective customers' needs, we have built both two-track and three-track machines. The two-track units have been used primarily in the industrial field for the purely investigative purposes of localizing and subjectively analyzing sound sources, or making sounds subjectively appear more realistic. Two headphones, rather than two speakers, are generally employed. One track often is used also for quantitative measurement, while the other is used for running commentary. The three-track units have been used primarily where sound is to be reproduced by means of a loudspeaker system. Obviously with three-track equipment it is possible to use only two tracks if headphones are preferred.

In the case of loudspeakers, listening-room acoustics are all-important, and must be taken into consideration, but this matter is beyond the scope of the present paper.*

In recording multichannel sound for later reproduction, we have not only verified all the findings of the Bell Laboratories' experiments of 20 years ago, but also we have run into one other problem. Since the Bell Laboratories' experiments were all concerned with instantaneous transmission of the original sound, time-lag effects between channels were not factors. Normal time lags are desirable. A recorder, basically, is a time-storage device. In delaying time all the channels must be delayed by the same amount, and, since they are all recorded side by side on the same tape, it might be assumed they must all be

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(This paper was first received on September 1, 1953, and in revised form on December 9, 1953.)

* R. J. Tinkham, "Binaural or stereophonic?," *Audio Eng.*, *37, No. 1:* Jan. 1953.

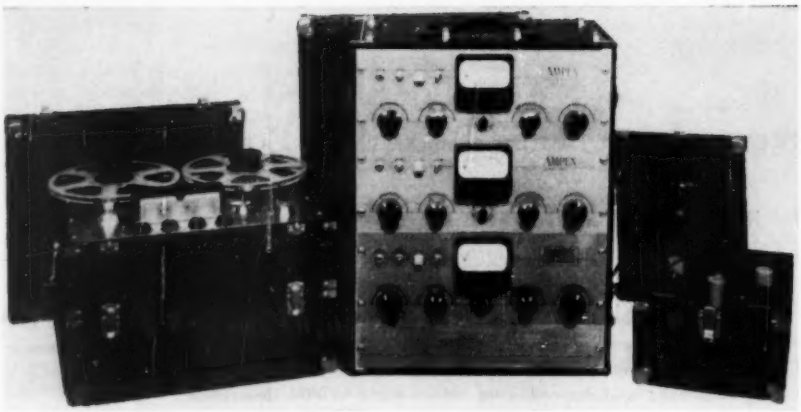

Fig. 1. Complete 3-channel stereophonic recorder

reproduced at the same time. That is what was thought at first, but it was found that while all of the heads were side by side, any deviation of spacing longitudinally with respect to the direction of tape motion introduced small constant time differences between channels.

This has the effect of making the apparent location of a given source, when reproduced, deviate from its actual original position. The angle of deviation increases as the time differential increases, and can be calculated. Therefore, all the heads must have the smallest possible error in parallel alignment. Some manufacturers use the same heads for both recording and reproducing. Here, obviously, there is no time error. But should such a recording be played on another machine, the head spacing cannot be different from the first without running afoul of this time-phase shift.

This equipment uses two separate sets of heads and amplifiers; one set for recording, and one for playing back the same record an instant after it has been made. This method has obvious monitoring advantages during the recording of a program, and it involves the difficulty for the manufacturer of making it necessary to build high accuracy into the head spacing. This problem and the one of inductive crosstalk between adjacent channels (30+ db) have been worked out.

Description of Equipment

The two- and three-track (Fig. 1) Ampex systems are housed in three luggage cases. One case contains the mechanical equipment involved in tape motion, the second contains the requisite number of combined record-playback amplifiers, each with separate controls and meter. The third case contains the power supplies for the amplifiers. All parts, optionally, may be mounted in a standard 19-in. rack.

The new Series 350 Ampex mechanical assembly (Fig. 2) is mounted on a $15\frac{3}{4} \times 19$-in. panel. Each reel turntable is driven by its own torque motor, and each motor is equipped with a solenoid-actuated brake, self-energizing in the proper direction.

A ball-bearing mounted flywheel, driven by the passage of the tape around a drum mounted on the same shaft and above the panel, stabilizes the tape motion as it approaches the head

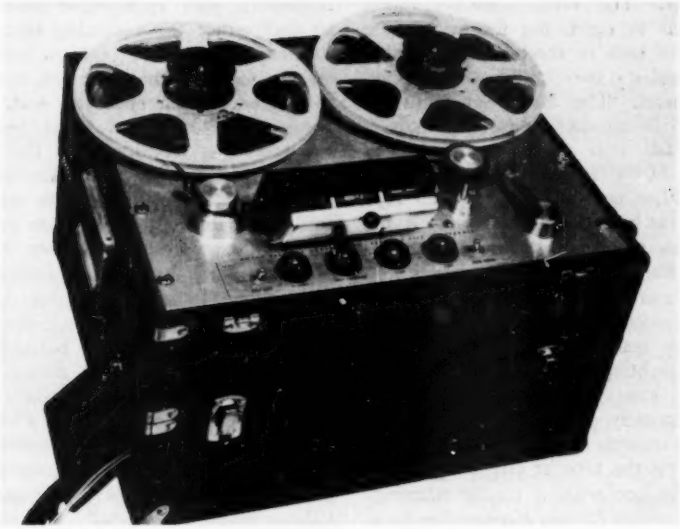

Fig. 2. Mechanical assembly, 3-channel stereophonic recorder.

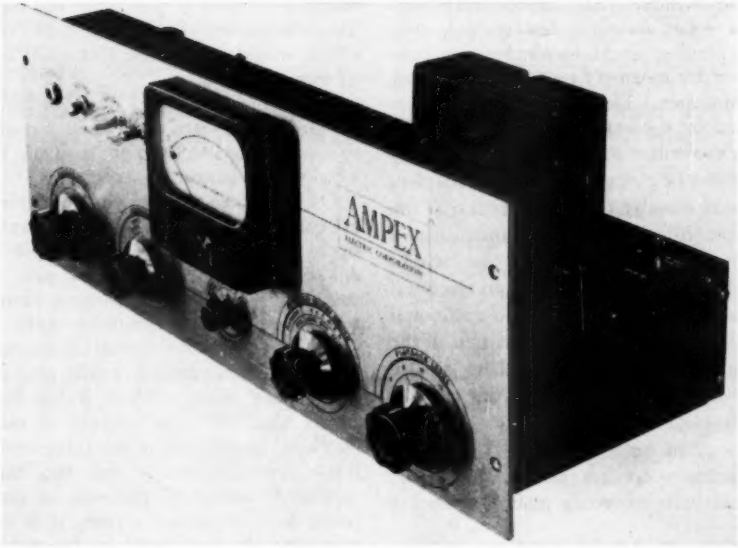

Fig. 3. Single record-reproduce amplifier. One is used for each channel.

assembly. The head assembly holds, from left to right, the full-track erase head, the two- or three-track recording head, and the two- or three-track playback head. The heads are suitably shielded in mu-metal cans, with covers which fall into place as the hinged portion of the assembly is lowered into place, after tape threading. The tape is accurately guided onto and off the heads by means of Pyrex glass guides spaced the width of the tape apart, and approximately at the entrance and exit of the assembly. The tape is pulled over the heads by means of a pinch drive consisting of a capstan and rubber capstan idler roller. The capstan is the accurately ground shaft of a dual-speed hysteresis motor, and is capable of driving the tape at either $7\frac{1}{2}$ in./sec or 15 in./sec with a timing accuracy of ± 3.6 sec in 30 min of recording time. $3\frac{3}{4}$-in. or $7\frac{1}{2}$-in. machines are also available.

The capstan motor is equipped with a flywheel, and speed is changed by a toggle switch. All mechanical functions — fast forward, fast rewind, stop and playing speed forward — are controlled by means of momentary contact pushbuttons. Electrical memory is furnished by d-c actuated relays. Therefore, the entire Speed Lock* equipment may also be plugged into the mechanism to make possible the synchronizing of the equipment with motion-picture camera and projector equipment to within 0.001-sec accuracy. This is an electrical arrangement and requires no additional heads or mechanical modification to the equipment. This synchronizing device may be used with any recorder without mechanical change. Only electrical connections need be made.

Each separate amplifier channel (Fig. 3) has both recording and reproducing amplifiers, with appropriate switching, so that either the incoming signal on that channel, or the signal just recorded on the tape for that channel, may be monitored. Each standard 4-in. (vu) meter may also be switched between the recording amplifier and the playback amplifier. Erase and bias voltages for each channel may also be read on this meter through appropriate switching. The recording amplifier has a choice of three inputs: low-impedance microphone, balanced, and unbalanced bridge input. The playback amplifier delivers +4 vu across a balanced or unbalanced 600-ohm line output, and an internal 600-ohm load resistor may be cut in or out by means of a switch. Suitable gain controls are provided for each input and output. Erase and bias current is obtained from a push-pull oscillator using a toroidally wound coil and is tuned to approximately 100 kc. This oscillator is mounted integrally on one of the amplifiers and its output is fed to separate buffer amplifiers associated with each of the other channels. This eliminates the possibility of beats which would exist if each channel had its own oscillator.

The power supplies are straightforward. They are mounted separately to reduce hum pickup and to divide the weight into convenient packages.

On the three-track system the tracks are each 0.040 in. wide and are separated by blank tape space of about 0.050 in. All three tracks lie side by side on standard $\frac{1}{4}$-in. tape. With such narrow tracks, some signal-to-noise ratio is sacrificed (55 db overall achieved). A restricted bandwidth would give less background noise. While it has been stated that we can tolerate a more restricted bandwidth, when using multitrack reproduction to get the same subjective feeling of presence as compared to a monaural system, it is also true that the full auditory bandwidth will give even more realism to the sound.

* Walter T. Selsted, "Synchronous recording on $\frac{1}{4}$-in. magnetic tape," *Jour. SMPTE, 55:* 279–284, Sept. 1950.

Stainless-Steel Developing-Machine Rollers

By A. H. VACHON

A NEW LIGHTWEIGHT stainless-steel developing-machine roller for 16mm and 35mm film has been devised by the Engineering Division of the National Film Board of Canada. The rollers are manufactured and supplied by The Ketchum Manufacturing Co., Ltd., P.O. Box 388, Ottawa, Canada.

Stainless-steel rollers were developed in order to eliminate the disadvantages encountered with the usual composition rollers, namely the difficulty of cleaning and the wear caused by cleaning and handling. At the National Film Board, the use of stainless-steel rollers has practically eliminated the need for replacements.

The roller is made from 26-gauge stock and composed of four separate parts. Two identical sides and two identical bearing cups are spot-welded into one finished unit. Figure 1 is a design drawing of the complete roller. Various stages of blanking and forming the material are shown in Fig. 2. Figure 3 is a completed side coming off the press. Figure 4 shows an actual bank of rollers which have been in operation on one of our developing machines.

The individual rollers weigh approximately 2½ oz, are easy to clean, and pick up very little foreign matter. The National Film Board has put about 500 of these rollers into use over the past 18 months and has found their performance superior to that of any rollers previously used.

Presented on October 6, 1953, at the Society's Convention at New York by A. H. Vachon, National Film Board of Canada, 35 John St., Ottawa, Canada.
(This paper was received Nov. 28, 1953.)

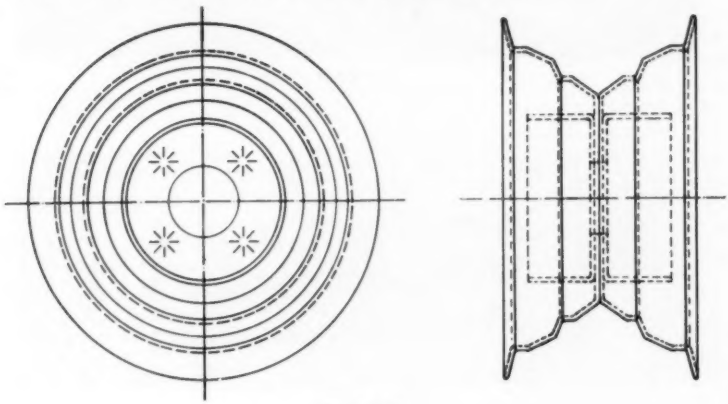

Figure 1

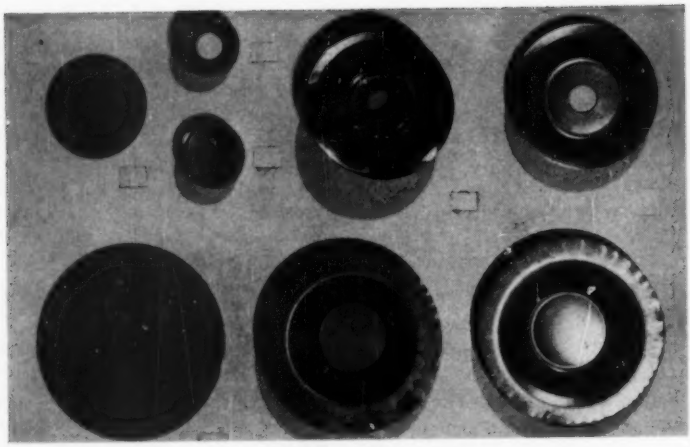

Figure 2

Figure 3

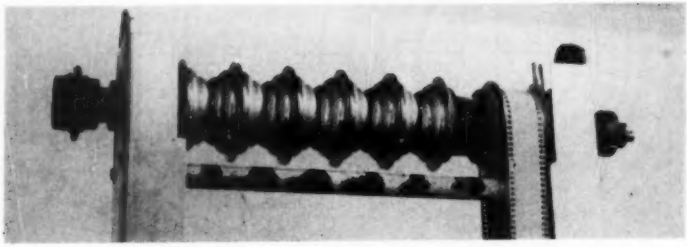

Figure 4

Use of the 16mm Sound-Service Test Film — SPSA

By WILLIAM C. EVERS

Among the many specialized duties which confront every audio-visual director is that of maintaining high-quality performance of projection equipment. Because the typical director does not have the time or the inclination to become an electronics engineer or repairman, which he needs to be if he does much work with a sound projector, he needs some objective means of judging the quality of performance or diagnosing trouble.

Here is where the various test films available from the Society of Motion Picture and Television Engineers help the audio-visual director. With these he can check to see that a projector is performing up to standard, or that a service man has repaired a projector competently. Incidentally, some of the better service agencies are using these films to aid in locating the cause of trouble, as well as to double-check work before returning the equipment to the customer.

One film which combines tests of the accuracy needed to take much of the subjectivity out of projector testing and establish it on an objective basis is the *16mm Sound Service Test Film.** Properly used and interpreted, the film will determine whether poor sound is the fault of equipment performance and the nature of the trouble, if it is in the projector. The description of the film which follows is based on the manual provided by the producer.

The different technical test sections will be presented in the following order: sound-focusing test for checking the position of the sound lenses so that the scanning beam from the exciter lamp will be in sharp focus on the sound track; the buzz-track test for making certain that the sound track is in the proper lateral position as it moves around the sound drum; and a frequency-response test which presents tones of twelve different frequencies for ascertaining whether the sound system reproduces both high and low frequencies in a satisfactory manner. In addition to the three technical sections, there are four sections for testing title music, dialog, piano music, and orchestral music — all of which have been recorded with great accuracy and care. These sections are also useful for checking room acoustics. A comparison of a projector's sound quality in rooms of various sizes will reveal differences in acoustics.

Instructions for the use of this film and its interpretation are discussed below. Captions projected on the screen while the film is being run describe the sound being presented and criteria for evaluating it.

Title Music. The orchestra music in this section contains both high- and low-frequency tones. If the sound system is adjusted properly, the tones are clear

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A contribution by William C. Evers, Supervisor, Audio-Visual Center, Indiana University, 1804 East Tenth St., Bloomington, Ind.; reprinted here from the *Bulletin* for February 1953 of the Indiana University Audio-Visual Center.

* Can be purchased for $18.00 from the Society of Motion Picture and Television Engineers, 40 W. 40 St., New York 18. Also available on a rental basis from the Audio-Visual Center, $2.00 for one to five days' use.

and full. The sound is crisp and without the shakiness of tone called "flutter."

Sound-Focusing Test. This section determines whether the sound-track scanning beam (that beam of light from the exciter lamp which is focused on the sound track by means of the sound lenses) is correctly focused upon the sound track. Correct adjustment here is indicated by maximum loudness of tone from the speaker. This test is especially pertinent for those projectors that have a fidelity lever which can be used to move the sound lenses into sharper focus. For projectors not having a fidelity lever it is recommended that a careful shop adjustment be made, if by using other tests it appears that the scanning beam is out of focus. This section of the test is 15 ft in length, with a 5000-cycle square-wave track, and will run for about 25 sec.

Buzz Track. In this test no sound is good sound, since a projector in proper adjustment will reproduce no sound at all. This will indicate that the scanning beam is properly aligned and that the film does not weave from one side to the other. Along each edge of the sound-track and just outside the sound-track area a tone has been recorded. On the edge nearer the edge of the film, a 1000-cycle (high) tone is recorded; on the edge nearer the picture area there is a 300-cycle (low) tone. Therefore, if the guides which position the film laterally are out of adjustment, one tone or the other will be heard. If the 1000-cycle tone is heard, the scanning beam is too near the edge of the film; if the 300-cycle tone is heard, the beam is too far from the film's edge and too near the picture area. Adjusting the film guides laterally should eliminate both tones. When both tones are heard, the scanning beam is not focused at the proper distance. An indication that the film is weaving at the sound drum is given when first one tone, then the other, is heard.

Frequency Response. This section will enable the listener to evaluate the frequency response of the projector. There are 12 different frequencies recorded, each of which runs for about 10 sec. Following are the steps in utilizing the section. While a 400-cycle tone is being reproduced, the tone control should be set at normal and the volume adjusted to a comfortable listening level. Following the 400-cycle tone are the following, each for a duration of approximately 10 sec: 50, 100, 200, 300, 500, 1000, 2000, 3000, 4000, 5000 and 6000 cycles. Immediately after the 6000-cycle tone, there is again a 400-cycle tone, which serves as a volume-level check. It should be of the same volume as the initial tone.

All tones in the series should be clearly heard and none should be too loud. If this is not the case, the projector is not functioning properly. If it is apparent from the sound-focusing and buzz-track sections that the sound optical system is in proper adjustment, failure in this test indicates trouble in the amplifier or loudspeaker system.

Dialog. Since many educational films are of the narration type, this is a valuable section. It is an example of good recording, with the quality of sound surpassing the visuals. If the loudspeaker is properly placed in relation to the screen there will be the feeling that the actors are in the room with the audience and that the spoken words are actually coming from their mouths. This section is also especially valuable for evaluating acoustical situations.

Piano Music. Film audiences often wonder whether unsatisfactory sound which sometimes results from the use of piano music in the sound track is due to the projector or whether it is due to an inferior sound recording. This section is accurate and reproduces the high

and low tones well without a noticeable flutter or waver on the sustained notes. Failure in the test — that is, fluctuation in the sound — is an indication that the film is passing the sound scanning beam at a varying rate of speed.

Orchestral Music. This section should be played without increasing the volume in order to hear certain passages or decreasing it to listen to other passages comfortably. The various passages should reproduce with both the high and low frequencies clearly audible and without distortion.

The Society of Motion Picture and Television Engineers' catalog lists other test films which are available at nominal cost. The *16mm Sound Projector Test Film* is often used by equipment dealers to demonstrate the performance of their equipment; the *Multifrequency Test Film*, to obtain the electrical-frequency response at the output of the power amplifier; the *Buzz-Track Test Film*, to check the placement of the scanning beam; the *Scanning-Beam Illumination Test*, to check the eveness of light across the width of the sound track; the *Sound Focusing Test Film*, to focus the sound optical system of the projector; the *3000-Cycle Flutter Test Film*, to measure the flutter introduced by 16mm sound reproducers; and the *400-Cycle Level Test Film*, to furnish a standard of recorded signal level for use in measuring the effective amplification and sound output of 16mm projectors.

It is obvious that some of these films are for the purpose of making adjustments and actually servicing the sound system of projectors in situations where an output-meter is available; therefore the director probably will not use them as often as will his service man.

British Standard 1404 : 1953 — Screen Luminance (Brightness) for the Projection of 35mm Film

By W. WALLACE LOZIER, *Chairman*, SMPTE Screen Brightness Committee

PUBLICATION of this standard in May 1953 revises the original one issued in 1947. The text of the Foreword, Specification and Appendix A is reprinted below. The complete text of the Standard also includes: Appendix B, "Report on the Tests Which Formed the Basis of the First Edition (1947) of This British Standard"; Appendix C, "Report on Tests Made to Provide Data for the 1953 Edition of B. S. 1404"; and Appendix D, "Notes on the Method of Measurement Specified in Appendix A."

Appendix B reports the results of viewing tests of 35mm motion pictures under controlled conditions at various screen-brightness levels and the considerations which led to the 1947 Standard brightness limits.

Appendix C reports the results of a recent series of measurements of screen brightness and related factors in 33 British theaters.

Appendix D cites the reasons for the choice of the specified type of meter and method of measurement.

Interesting supplementary comments on this British Standard are given in "Some

Notes on the British Standard of Screen Luminance" by F. S. Hawkins, *Brit. Kinemat. 23:* 43–45, Aug. 1953.

The British Standard is considerably more inclusive than the American one ("Revision of Screen Brightness Standard," *Jour. SMPTE, 58:* 452, May 1952; and "American Standard Screen Brightness for 35mm Motion Pictures," *Jour. SMPTE, 60:* 630, May 1953). The British Standard contains a specification of variation of brightness across the screen and the method of measurement in addition to the recommended level of brightness at the center of the screen. Some of these subjects are still under consideration in this country and are not included in the American Standard.

The following table shows the comparison of specified brightness at the center of the screen contained in the current American, British and French Standards. It is interesting to note that all three countries have arrived at approximately the same brightness range.

	Foot-Lamberts at Center of Screen		
	Nominal	*Minimum*	*Maximum*
American Standard PH22.39-1953...	10	9	14
British Standard BS 1404:1953...	—	8	16
French Standard NFS 27-003*....	10.2	7.3	14.6

* Specified French photometric units have been converted to foot-lamberts.

British Standard Specification for Screen Luminance (Brightness) for the Projection of 35mm Film

FOREWORD

The British Standard for screen brightness, prepared under the authority of the Cinematograph Industry Standards Committee, was first issued in 1947. It recommended a range of screen brightness, measured normal to the centre of the screen, for the projection of 35 mm. colour and black and white film, and recorded the results of the comprehensive series of investigations which had been carried out in order to provide data for the establishment of this recommended range.

It was then envisaged that experience would enable a more precise standard to be laid down in a future edition, and that later it would also be found possible to specify the method of measurement.

Since the first edition was published, further comprehensive investigations have been made, both in regard to the actual range of luminance with particular reference to the position of the viewer in the auditorium, and also in regard to methods of measurement.

This revision is more specific in regard to the value of screen luminance, which now has to lie within a specified range as measured on a horizontal axis both at the centre and sides of the screen, and as seen from any seat in the auditorium, and it also specifies a standard method of measurement. It is intended to be applicable to the type of screen with black masking which is in general use at the present time.

The appendix to the first edition, which recorded the earlier investigations, is reproduced, and a further appendix, giving a report of the investigations made since, is also included.

To conform to modern terminology, the expression 'screen luminance' has been adopted in place of 'screen brightness.'

SPECIFICATION

Scope

1. This British Standard relates to screen luminance (brightness) for the projection of 35 mm cinematograph film.

Screen Luminance (Brightness)

2. The luminance (brightness) of the screen, measured from any seat in the auditorium by the method and under the conditions specified in Appendix A, shall be as follows: The luminance of the centre shall be not less than eight foot-lamberts and not more than sixteen, and the luminance of each side measured on the horizontal axis shall lie between 0.6 and 0.75 times the measured luminance at the centre, and shall preferably be as near as practicable to 0.7.

NOTE 1. For the purposes of this specification, the 'side' is defined as a position on the horizontal axis of the screen, 5 per cent of the width of the screen inwards from the edge.

NOTE 2. It has been observed that a greater variation in the ratio of side to centre luminance is tolerable with colour film than with black and white film. It has nevertheless been found that under general cinema conditions a ratio of 0.8 or greater is uneconomically achieved and tends to reduce the artistic quality of the projected picture by reason of a reduction of its apparent brillance, and that a ratio of 0.55 or less is undesirable because of an objectionable falling off of the luminance of the sides and corners, with a consequent reduction in the artistic quality of the picture.

APPENDIX A

Conditions and Method for Measuring Screen Luminance

1. Conditions of Measurement

The measurement of the luminance of the screen shall be made under the following conditions, which shall remain constant throughout the complete series of measurements.

a. The projector shall be running under normal operating conditions, with no film in the gate.

b. The optical system shall be aligned so that the area of maximum luminance is at the centre of the screen.

c. The lighting in the auditorium shall be that normally used when a film is being projected.

2. Photometer

The screen luminance shall be measured with a visual photometer in which the screen or a suitable part of it is viewed through a small telescope, which has centrally in its field of view a small comparison spot, obscuring not more than 1° of this field. The comparison spot is illuminated to a sensibly uniform luminance by a small electric lamp, the luminous intensity of which can be adjusted so as to be maintained constant. The luminance of the comparison spot is to be capable of variation by suitable means, e.g. neutral wedges, so as to be made to match that of the screen whose luminance is required. The illumination of the comparison spot by the small lamp is kept constant, and means are provided to ensure that this is achieved. The device which alters the luminance of the comparison spot is calibrated so that the luminance of the spot, and hence that of the screen with which it is matched, can be determined.

The photometer shall be capable of measuring down to 0.2 foot-lamberts and the error in the indication of the instrument at any point within the effective range shall not exceed 20 per cent of the indication.

NOTE. Information as to where such instruments can be obtained is available on application to the Director, British Standards Institution, 24 Victoria Street, London, S.W.1.

3. Number of Measurements

At least four measurements of the luminance of each selected portion of the screen shall be made from each selected position in the auditorium. The mean value of these four measurements shall be regarded as the measured luminance of that portion of the screen as viewed from that position in the auditorium. If more than one observer takes measurements, then each observer shall make the same number of observations, which shall be not less than four for each observer.

Theater Engineering Committee Report

By BENJAMIN SCHLANGER, Chairman

THE SMPTE SENT theater owners a screen questionnaire dated May 25, 1953, that was designed to help the industry determine how much larger most theater screens could be made and also what limits on picture aspect-ratio accommodation are fixed by physical conditions in the theaters. Out of 370 questionnaires returned, 330 had sufficient data to be useful in the study that is reported here.

Because the number of theaters represented is so small, the results actually show a number of typical situations that do not necessarily align with any national averages that might have been drawn, had most theaters in the country been included. But the value of the information derived should not be minimized on this score.

It is desirable to compare the number of surveyed theaters in certain categories with the number of theaters in those same categories throughout the United States. To make this possible, theaters were considered as falling into three groups; those with up to 500 seats being the first group, the second group to include those with 500 to 1500 seats and the third group those with 1500 seats or more. The percentage of surveyed theaters in these groups and the actual percentage of U.S. theaters falling in the same grouping are as follows:

Group	*% Theaters Surveyed*	*% Theaters in U.S.*	
Up to 500	18	51.9	According to statistics obtained from MPAA
500–1500	46	42.5	
Over 1500	36	5.6	

Although the sample includes information on a disproportionate number of large-circuit theaters and large-seating capacity theaters and in consequence, theaters in densely populated areas, it was felt that much worth-while information was still to be derived because the percentage of surveyed theaters that fall in the middle group of from 500 to 1500 seats differed from the percentage of this group in the whole United States by only a few percent.

Referring to the accompanying tabulation, column 1 shows the average maximum viewing distances that were found in this survey. In the first group the average maximum viewing distance is about 80 ft; in the second group, about 103 ft; and in the third group this distance is about 120 ft. The range in the latter group is quite wide, however, the lowest distance being about 100 ft and the highest being about 180 ft. This factor of viewing distance is very important because it helps to determine picture size or, stated in other terms, minimum angle subtended in viewing motion pictures from the back row. This information will also be helpful in reaching conclusions in relation to picture aspect ratio.

The survey also supplied valuable information on average picture height available. This is a key figure, which will have influence on the determination of an optimum picture aspect ratio. In column 2, in the smaller theater group, the average picture height available is a little under 15 ft. In the second grouping (of 500 to 1500 seats) the average picture height is about 19 ft, ranging from a low of 16 ft to a high of 23 ft. In the third group, the height does not increase as much as one might expect, the average height being only 21½ ft, or only about two feet more than in the group of theaters between 500 and 1500 seats. This limitation is due, in the latter group of large theaters, mostly because of the overhang of balconies. Most of these theaters have balconies, causing this restriction of view of increased screen height. These large theaters were patterned after the old stage theaters where the trapeze act set the

Presented on October 9, 1953, at the Society's Convention at New York by Benjamin Schlanger, Theater Consultant, 35 W. 53 St., New York 19, N.Y.

SMPTE Indoor Theater Survey Data.

Seating Capacity	1 ft	1 in.	2 ft	2 in.	3	4	5 ft	5 in.	6 ft	6 in.	7 ft	7 in.	8 ft	8 in.	9 ft	9 in.	10	11	12
Up to 300	77	5	13	7	1.5	Less	25	10									9		
301 to 400	79	3	14	6	1.77	than	26	5	80	4	26	9	14	8	26	5	22	60	51.9%
401 to 500	82	6	15	2	1.87	38 ft	27	6									29	18%	
501 to 600	83	5	16	0	1.91	avail-able	27	10									21		
601 to 700	84	7	18	8	1.81		28	2									17		
701 to 800	91	4	18	8	1.87		30	5									20		
801 to 900	84	2	18	0	1.88		28	0									15	154	42.5%
901 to 1000	95	0	19	0	1.94	1.85	31	8	102	7	34	10	19	2	34	6	26		
1001 to 1100	106	11	20	0	2.00	1.80	35	5									11		
1101 to 1200	107	4	19	10	2.27	1.97	35	9									11	46%	
1201 to 1300	106	9	21	4	2.25	1.84	35	4									10		
1301 to 1400	112	6	21	8	2.10	1.79	37	6									11		
1401 to 1500	107	0	22	9	2.16	1.78	35	7									12		
1501 to 1600	104	0	20	10	2.14	1.80	34	8									13		
1601 to 1700	106	0	22	0	2.30	1.79	35	4									14		
1701 to 1800	120	2	22	2	2.23	1.78	40	0									16		
1801 to 1900	105	11	20	6	2.16	1.86	35	4	120	4	40	6	21	6	38	8	9	120	5.6%
1901 to 2000	113	2	20	5	2.06	1.88	37	9									8		
Over 2000	129	9	21	8	2.19	1.77	43	4									60	36%	

(1) Average maximum viewing distance
(2) Average picture height available
(3) Aspect ratio for maximum picture height & width available
(4) Aspect ratio for maximum picture height available and proposed maximum of 38-ft picture width
(5) Picture width on 3W basis
(6) Average maximum viewing distance by groups
(7) Average picture width on 3W basis by groups
(8) Average picture height available by groups
(9) Average picture height available by groups used to give picture width for 1.8 to 1 aspect
(10) Number of theaters
(11) Number of theaters by groups and percentage of total survey
(12) Percentage of total number of theaters in U.S. for same grouping

height limitation to about 20 ft above the stage floor.

The next compilation of figures that might be of interest is available aspect ratio. The maximum height and maximum width available indicate the following aspect ratios. In the first group the aspect ratio ranged from 1.5 to 1.87:1.00. In the second group the aspect ratio ranged from a low of 1.81 to a high of 2.27:1.00, the average being about 1.9:1.00 in this latter group. In the group of 1500 seats and over, the low aspect ratio was 2.06:1.00 and the high 2.30:1.00. If an aspect ratio greater than the average (and the average in these very large theaters is about 2.2) were desired, a sacrifice in the height of the picture would have to be accepted.

In column 4 is an interpolation of what would happen to aspect ratio, if all the available height and an arbitrary maximum width of 38 ft were to be used. The 38-ft maximum was chosen because greater magnification of picture image from 35mm film will show disturbing film grain. The average maximum aspect ratio under these conditions comes close to 1.8:1.00.

Discussion

Morton D. O'Brien (*Assistant Director, Projection and Sound, Loew's Theaters*): In making your computations did you base them on the fact that every seat in the theater was available at these ratios and these sizes of screens or did you incorporate a loss of a certain amount of seats in these theaters?

Mr. Schlanger: The interpolations made in this analysis were based on the assumption that all existing seating would remain in use, but knowing that there would necessarily be some existing seats nearer the screen that would be less desirable with bigger screens.

William A. Shurcliff (*Polaroid Corp.*): Do I understand that over half the theaters in the country then cannot accommodate an aspect ratio more than about 1.9 unless they cut down the height?

Mr. Schlanger: The survey indicates that this may be so.

Standards PH22.5, –.12 and –.93 Related to 16mm and 35mm Low-Shrink Film

Three American Standards, approved by the American Standards Association on December 17, 1953, are published on the following pages. Two (PH22.5-1953 and PH22.12-1953) are revisions of previous standards; PH22.93-1953 is a new standard. These three standards were published previously for trial and comment, and the background information on their development and processing will be found in the December 1952 *Journal*.—*Henry Kogel*, Staff Engineer

American Standard

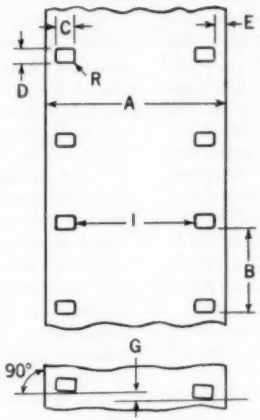
Dimensions for 16mm Film, Perforated Two Edges

ASA
Reg. U.S. Pat. Off.

PH22.5–1953

Revision of Z22.5–1947

*UDC 778.5



Dimensions	Inches	Millimeters
*A	0.629 ± 0.001	15.98 ± 0.03
†B	0.3000 ± 0.0005	7.620 ± 0.013
C	0.0720 ± 0.0004	1.83 ± 0.01
D	0.0500 ± 0.0004	1.27 ± 0.01
*E	0.036 ± 0.002	0.91 ± 0.05
G	Not > 0.001	Not > 0.025
I	0.413 ± 0.001	10.490 ± 0.025
‡L	30.00 ± 0.03	762.00 ± 0.76
R	0.010	0.25

These dimensions and tolerances apply to negative and positive raw stock immediately after cutting and perforating.

* For low-shrink film as defined in Appendix 2, A shall be 0.628 ± 0.001 and E shall be 0.0355 ± 0.0020 in.

† In any group of four consecutive perforations, the maximum difference of pitch shall not exceed 0.001 in. and should be as much smaller as possible.

‡ This dimension represents the length of any 100 consecutive perforation intervals.

Approved December 17, 1953, by the American Standards Association, Incorporated
Sponsor: Society of Motion Picture and Television Engineers

*Universal Decimal Classification

Copyright 1954 by the American Standards Association, Incorporated
70 East Forty-fifth Street, New York 17, N. Y.

Printed in U.S.A.
ASA\M154

Price, 25 Cents

(These Appendixes are not a part of American Standard Dimensions for 16mm Film, Perforated Two Edges, PH22.5–1953.)

Appendix 1

The dimensions given in this standard represent the practice of film manufacturers in that the dimensions and tolerances are for film immediately after perforation. The punches and dies themselves are made to tolerances considerably smaller than those given, but owing to the fact that film is a plastic material, the dimensions of the slit and perforated film never agree exactly with the dimensions of the punches and dies. Shrinkage of the film, due to change in moisture content or loss of residual solvents, invariably results in a change in these dimensions during the life of the film. This change is generally uniform throughout the roll.

The uniformity of perforation is one of the most important of the variables affecting steadiness of projection.

Variations in pitch from roll to roll are of little significance compared to variations from one sprocket hole to the next. Actually, it is the maximum variation from one sprocket hole to the next within any small group that is important. This is one of the reasons for the method of specifying uniformity in dimension B.

Appendix 2

In the early days of 16mm film the safety base used for this film had the characteristic of shrinking very rapidly to a certain fairly definite amount and then not shrinking much more. Although this film tended to swell at high humidities, nevertheless the shrinkage that occurred in the package before the user received the film was always at least as great as any swell that might occur due to high humidities at the time of use. This meant that the user never encountered film, even at high humidities, that had greater width than that specified in the standards. This meant that camera and projector manufacturers seldom ran into trouble so long as their film gates would readily pass film at the upper limit of the slitting tolerances, namely 0.630 in.

Within the past few years, however, a safety base with lower shrinkage characteristics began to be used. Although this film was less susceptible than the previous film to swelling at high humidities, nevertheless the shrinkage characteristics were low enough so that this shrinkage did not always compensate for the swell at high humidities.

For this reason film slit at the mid point of the tolerance for width, namely 0.629 in., would occasionally swell at high humidities to such an extent that it would bind in film gates designed to pass film with the width of 0.630 in. The manufacturers, therefore, were compelled to slit at the lower edge of the tolerance permitted by the previous edition of this standard. Variations in their slitting width, however, sometimes produced film slit below the limits of the standard.

This revision has therefore been adopted in order that the manufacturers may slit low-shrink film within the standard and still produce film which does not exceed 0.630 in. even at high humidities.

For the purpose of this specification, low-shrink film base is film base which, when coated with emulsion and any other normal coating treatment, perforated, kept in the manufacturer's sealed container for 6 months, exposed, processed, and stored exposed to air for a period not to exceed 30 days at 65 to 75 F and 50 to 60% relative humidity and measured under like conditions of temperature and humidity, shall have shrunk not more than 0.2% from its original dimension at the time of perforating. The final measurement should be made after conditioning the film for 24 hours to a humidity of 55 $\pm$ 5%.

This definition of low-shrink film is to be used as a guide to film manufacturers, and departure therefrom shall not be cause for rejection of the film.

American Standard

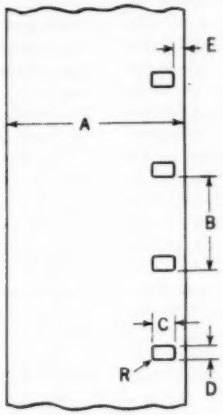
Dimensions for 16mm Film, Perforated One Edge

ASA
Reg. U.S. Pat. Off.

PH22.12–1953

Revision of Z22.12–1947

*UDC 778.5



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R	0.010	0.25

These dimensions and tolerances apply to negative and positive raw stock immediately after cutting and perforating.

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‡ This dimension represents the length of any 100 consecutive perforation intervals.

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ASA(M)54

Price, 25 Cents

(These Appendixes are not a part of American Standard Dimensions for 16mm Film, Perforated One Edge, PH22.12–1953.)

Appendix 1

The dimensions given in this standard represent the practice of film manufacturers in that the dimensions and tolerances are for film immediately after perforation. The punches and dies themselves are made to tolerances considerably smaller than those given, but owing to the fact that film is a plastic material, the dimensions of the slit and perforated film never agree exactly with the dimensions of the punches and dies. Shrinkage of the film, due to change in moisture content or loss of residual solvents, invariably results in a change in these dimensions during the life of the film. This change is generally uniform throughout the roll.

The uniformity of perforation is one of the most important of the variables affecting steadiness of projection.

Variations in pitch from roll to roll are of little significance compared to variations from one sprocket hole to the next. Actually, it is the maximum variation from one sprocket hole to the next within any small group that is important. This is one of the reasons for the method of specifying uniformity in dimension B.

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This revision has therefore been adopted in order that the manufacturers may slit low-shrink film within the standard and still produce film which does not exceed 0.630 in. even at high humidities.

For the purpose of this specification, low-shrink film base is film base which, when coated with emulsion and any other normal coating treatment, perforated, kept in the manufacturer's sealed container for 6 months, exposed, processed, and stored exposed to air for a period not to exceed 30 days at 65 to 75 F and 50 to 60% relative humidity and measured under like conditions of temperature and humidity, shall have shrunk not more than 0.2% from its original dimension at the time of perforating. The final measurement should be made after conditioning the film for 24 hours to a humidity of 55 ± 5%.

This definition of low-shrink film is to be used as a guide to film manufacturers, and departure therefrom shall not be cause for rejection of the film.

American Standard

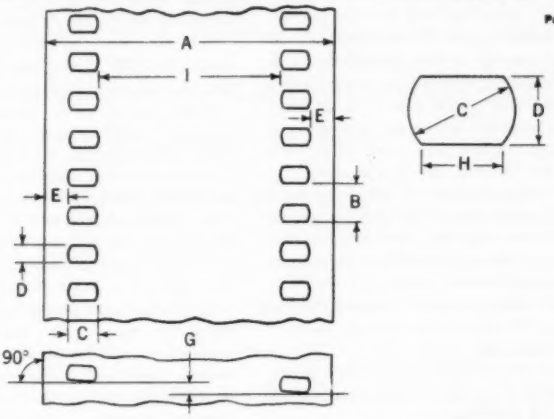
Dimensions for 35mm Motion-Picture Short-Pitch Negative Film

ASA

Reg. U.S. Pat. Off.

PH22.93–1953

*UDC 778.5



Dimensions	Inches	Millimeters
A	1.377 ± 0.001	34.98 ± 0.03
B	0.1866 ± 0.0005	4.740 ± 0.013
C	0.1100 ± 0.0004	2.794 ± 0.01
D	0.073 ± 0.0004	1.85 ± 0.01
E	0.079 ± 0.002	2.01 ± 0.05
G	Not > 0.001	Not > 0.025
*H	0.082	2.08
I	0.999 ± 0.002	25.37 ± 0.05
†L	18.66 ± 0.015	474.00 ± 0.38

These dimensions and tolerances apply to low-shrink negative raw stock immediately after cutting and perforating.

This film is used for motion-picture negatives and certain special processes.

* A calculated value for a dimension not measured routinely in production.

† This dimension represents the length of any 100 consecutive perforation intervals.

This standard is based on American Standard Cutting and Perforating Dimensions for 35-Millimeter Motion Picture Negative Raw Stock, Z22.34–1949 and differs only in the values of B and L and the addition of a second Appendix.

Approved December 17, 1953, by the American Standards Association, Incorporated
Sponsor: Society of Motion Picture and Television Engineers

*Universal Decimal Classification

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Price, 25 Cents

(These Appendixes are not a part of American Standard Dimensions for 35mm Motion-Picture Short-Pitch Negative Film, PH22.93–1953.)

Appendix 1

The dimensions given in this standard represent the practice of film manufacturers in that the dimensions and tolerances are for film immediately after perforation. The punches and dies themselves are made to tolerances considerably smaller than those given, but owing to the fact that film is a plastic material, the dimensions of the slit and perforated film never agree exactly with the dimensions of the punches and dies. Shrinkage of the film, due to change in moisture content or loss of residual solvents, invariably results in a change in these dimensions during the life of the film. This change is generally uniform throughout the roll.

The uniformity of perforation is one of the most important of the variables affecting steadiness of projection.

Variations in pitch from roll to roll are of little significance compared to variations from one sprocket hole to the next. Actually, it is the maximum variation from one sprocket hole to the next within any small group that is important.

Appendix 2

Most motion-picture film is printed on sprocket-type printers. Maximum steadiness and definition are secured on a sprocket-type printer when the negative film is somewhat shorter in pitch than the positive stock.

For many years, this difference in pitch has come about due to shrinkage of the negative film base on processing and aging.

There are currently becoming available new low-shrink film bases which do not shrink sufficiently to provide the necessary pitch differential between negative and print stock for proper printing on sprocket-type printers. This standard is intended to give dimensions for perforating low-shrink film material so that it will have, as nearly as possible, optimum dimensions at the time of printing.

For the purpose of this specification, low-shrink film base is film base which, when coated with emulsion and any other normal coating treatment, perforated, kept in the manufacturer's sealed container for 6 months, exposed, processed, and stored exposed to air for a period not to exceed 30 days at 65 to 75 F and 50 to 60% relative humidity and measured under like conditions of temperature and humidity, shall have shrunk not more than 0.2% from its original dimension at the time of perforating. The final measurement should be made after conditioning the film for 24 hours to a humidity of 55 $\pm$ 5%.

This definition of low-shrink film is to be used as a guide to film manufacturers, and departure therefrom shall not be cause for rejection of the film.

PH22.93–1953

American Standards for Still Photography

BELOW ARE LISTED the numbers and titles of recently approved American Standards in the field of still photography. Additional listings of such standards will be published in the *Journal* from time to time, as they are made available, as a service to those readers who maintain an active interest in still, as well as motion-picture photography. A previous enumeration of PH3 and PH4 Standards appeared on page 82 of the July 1953 *Journal*.

Photographic Sensitometry, PH2

Sensitometry and Grading of Photographic Papers, PH2.2-1953 (Revision of Z38.2.3-1947)

Exposure Guide Numbers for Photographic Lamps, PH2.4-1953

Photographic Apparatus, PH3

Specifications for Contact Printers, PH3.8-1953 (Revision of Z38.7.10-1944)

Specifications for Masks (Separate) for Use in Photographic Contact Printing of Roll Film Negatives, PH3.9-1953 (Revision of Z38.7.12-1944)

Dimensions for Stereo Still Pictures on 35-Millimeter Film, 5-Perforation Format, PH3.11-1953

Specifications for Attachment Threads for Lens Accessories, PH3.12-1953 (Revision of Z38.4.12-1944)

Dimensions of Front Lens Mounts for Cameras, PH3.14-1944 (Reaffirmation—formerly designated as Z38.4.10-1944)

Specifications for Printing Frames, PH3.15-1944 (Reaffirmation—formerly designated as Z38.7.11-1944)

Method for Determining Resolving Power of Lenses for Projectors for 35-Mm Slidefilm and 2- × 2-Inch Slides, PH3.16-1947 (Reaffirmation—formerly designated as Z38.7.16-1947)

Photographic Processing, PH4

Requirements for Photographic Grade Blotters, PH4.10-1953

Specification for Photographic Grade Ammonium Chloride, (NH_4Cl), PH4.183-1953

Specification for Photographic Grade Ammonium Sulfate, ($(NH_4)_2SO_4$), PH4.184-1953

Correction in the "Single-Copy" Printing of American Standard 16mm Motion Picture Projection Reels, PH22.11–1953

This American Standard as published in the September 1953 *Journal* is correct in its entirety. However, the Standard as published and released by ASA in October 1953 under the box heading "Revision of Z22.11-1941, Z52.33-1945 and PH22.11-1952" shows a typographical error in Table 2, col. 3, on page 2. The "Lateral run-out,' maximum" dimension should read "0.057" instead of "0.570." The American Standards Association plans to insert a correction slip with all PH22.11-1953 standards sold in future.

75th Convention and High-Speed Photography

Government and industrial workers are already inquiring about the high-speed photography sessions on the Spring Convention Program, to be held May 3–7 at the Hotel Statler, Washington, D.C. Because government employees often have to apply for travel authorization 90 days in advance, information will be released as soon as it becomes available.

Plans, still tentative but revised since the December *Journal*, now are that the Thursday Afternoon, May 6, session will be a very substantial session on high-speed photography of interest to specialists and the Society's membership in general. It will feature these two basic papers:

"The Photography of Motion" by Morton Sultanoff and John Waddell

"History of the Electronic Flash" by Harry Parker

Two briefer papers on high-speed photography techniques will also be scheduled for this session.

Then, for Friday morning, with the first of two television sessions running concurrently with it, there will be a second high-speed photography session to include papers on techniques and applications and demonstrations.

The Postal Announcement, probably combining for economy's sake the customary folded post card (with hotel rates) and the major aspects of the Advance Program, is scheduled to go out late this month. Program Chairman Joe Aiken and Vice-Chairman John Waddell who is working particularly on the high-speed sessions assure the membership that traveling plans for the high-speed sessions can be made firmly on the above information.

Many papers in addition to those listed in the December *Journal* are now covered by Author Forms. The deadline for Author Forms to reach Chairman Aiken is February 22 — and March 29 for copies of manuscripts and illustrations to reach Society headquarters.

Author Forms are available from any of the Papers Committee listed in the November *Journal*, or from Society headquarters. Author Forms should be submitted early to permit the scheduling of papers.

Central Section Meetings

The Central Section of the SMPTE met at 8:00 p.m. on November 19, 1953, at the Bell & Howell plant, Chicago. Malcolm G. Townsley, P. C. Foote, A. B. Cox and H. H. Brauer discussed photographic and sound techniques in connection with wide-screen processes, and the 16mm and 35mm anamorphic lenses being produced by Bell & Howell were shown. At the conclusion of the talks the members saw some 16mm wide-screen reduction prints from a Marilyn Monroe picture and from *The Robe*, and some 16mm wide-screen originals made by Bell & Howell employees. Approximately 225 persons were in attendance.

On December 10, 1953, the Section met at 8:00 p.m. in the Civic Theatre at Television Station WBKB, 20 N. Wacker Dr., Chicago. James L. Lahey, President of Dage Electronics Corp., Beech Grove, Ind., presented a paper on "The Dage Vidicon Camera and Associated Equipment for Film and Studio Use." At the conclusion of Mr. Lahey's paper a film, *The Living City*, supplied by Encyclopedia Britannica, was shown on the Dage equipment. A matching print was televised at the same time through a closed circuit on WBKB studio equipment. Matching monitors were set up on the stage so that the entire audience could check the visual results. After the film, two cameras, the Vidicon and the studio's standard equipment camera, were used for live pick-ups from the stage.

A Symposium Panel was established under George Ives. The members of the panel answered all questions concerning the new equipment vs. the standard studio equipment and assisted with the demonstration. There were 125 present at the meeting.—*James L. Wassell*, Secretary-Treasurer, Central Section, 247 E. Ontario St., Chicago 11.

Pacific Coast Section Meeting

The October meeting of the Pacific Coast Section of the SMPTE was held on October 20, 1953, at the Twentieth Century-Fox Studios in Beverly Hills. The subject of the evening was "CinemaScope at Twentieth Century-Fox." Due to the unusual interest on the part of our members in this program it was necessary to hold a dual session, one commencing at 7 o'clock, and the other at 8:30. The attendance at each session was limited to 165 persons, and both sessions were filled to capacity.

The meeting featured a presentation of the technical aspects of the CinemaScope process, with specific reference to photography, release printing and exhibition. The group was very appreciative of the concise summary of the CinemaScope engineering features efficiently presented by Lorin Grignon. The program was moderated by Mr. Grignon, and included the following topics:

(1) *The CinemaScope Composite Film.* Mr. Grignon outlined performance requirements and technical considerations leading to the choice of picture, soundtrack and sprocket-hole dimensions, and methods of applying the magnetic soundtracks to the film.

(2) *The CinemaScope Picture.* Joe MacDonald, cameraman for Twentieth Century-Fox, discussed factors pertaining to the photographing, processing and projection of CinemaScope.

(3) *A Sound Printer for CinemaScope.* Ed Templin (Program Chairman of the Pacific Coast Section of SMPTE), of Westrex Corp., described a new multiple-output electrical sound printer for CinemaScope release prints.

(4) *An Exhibition of CinemaScope*, and

(5) *CinemaScope Demonstration.* This gave the members an opportunity to view the process.—*Philip G. Caldwell*, Secretary-Treasurer, Pacific Coast Section, ABC Television Center, Hollywood 27, Calif.

Revised Roster of Atlantic Coast Section Officers

The elected Chairman of the Section, John G. Stott, has departed the environs of New York City to serve the industry in the Color Technology Division, Kodak Park, Eastman Kodak Co., Rochester 4, N.Y., so the roster of Section Officers now at work is:

Everett Miller, Chairman
George H. Gordon, Secretary-Treasurer
George Lewin, Manager
Charles W. Seager, Manager
J. Paul Weiss, Manager

Managers serving their second year are R. C. Holslag, M. H. Searle, R. T. Van Niman.

Book Reviews

The Technique of Film Editing: Basic Principles for TV

Written and compiled by Karel Reisz for the British Film Academy. Published (1953) by Farrar, Straus and Young, 101 Fifth Ave., New York 3, N.Y. 276 pp. + 6 pp. bibliography and glossary + 3 pp. index. Illus. $5\frac{3}{4} \times 8\frac{3}{4}$ in. $7.50.

This is the best book yet available on film editing, either for the layman or for those learning the craft. For some strange reason, in spite of all the books that have been written about film, very few have been about film editing, and even they have mainly consisted of one man's personal and individual approach to the subject. Now for the first time we have a comprehensive book, attempting to make clear "the pivotal contribution of the film editor" to film-making as a whole.

The first quarter of the book is devoted to a short history of editing, showing how the need for it arose, and how it has been affected by the varying requirements of the silent and sound eras.

The main body (and most effective part) of the book goes on to illustrate, with numerous examples, how the elements of editing have been handled by different editors, for quite different purposes. It is thus a book of editing *practice* rather than theory, showing how editing *is* done rather than how it should be done. There are sections on action cutting, dialogue, comedy, "montage," reportage, imaginative documentary, films of ideas, teaching films for the classroom, newsreels and others.

To achieve this, the author has enlisted the expert advice of ten of Britain's top film editors in various fields. Many excellent extracts from finished films illustrate typical points in the text. Each extract includes a shot-by-shot description, the length of each shot, and a sound track breakdown of music, effects, dialogue or commentary, together with still frames from each shot wherever necessary. Only well-known English-language films (from the U.S. and the U.K.) are included, to avoid language problems. Among these are *Birth of a Nation, Naked City, Topper Returns, Citizen Kane, Rope, Great Expectations, Lady from Shanghai, Tobacco Road, Louisiana Story, Night Mail* (about two dozen different films altogether).

The best quarter of the book deals with the "principles of editing," covering such problems as continuity, "smooth" cutting, timing, pace, rhythm, etc. What there is of it is good, so far as it goes. But there is all too little. Even with this book, there is still room for another dealing with this part of the subject, similarly but much more fully.

Finally, there is a short appendix on cutting room procedure, a bibliography and a glossary, explaining the few technical terms used in the text.

The book's subtitle "Basic Principles for TV" is misleading. It does not appear in the original English edition, and seems to have been added to the American edition as an afterthought to capitalize on the popularity of TV. Actually there is hardly a mention of TV in the text, and there is no material whatever dealing with TV situations. This does not, of course, prevent TV directors from profiting strongly from a thorough knowledge of editing. But readers will be disappointed if they look for anything other than *film* editing in this book.

The price ($7.50) is due to the copious illustrations which are part of the book's special value. The language is simple and clear.—*Thomas C. Daly*, National Film Board of Canada, Ottawa, Ontario.

Television

By F. Kerkhof and W. Werner. Published (1952) by Philips' Technical Library, N. V. Philips' Gloeilampenfabrieken, Eindhoven, Holland. Distributed in U.S. and Canada by Elsevier Press, 402 Lovett Blvd., Houston 6, Tex. i—xv + 406 pp. + 10 pp. appendix + 12 pp. literature list + 4 pp. index. 400 illus. Numerous tables. 6 × 9 in. $7.75.

The subtitle of this book is a guide to its contents: "An Introduction to the Physical and Technical Principles of Television, With Comprehensive Descriptions of Various Electrical Circuits."

Messrs. Kerkhof and Werner are principals of the Television Development Laboratory of Philips Industries — Eindhoven (Holland). The book is one of a group of twenty-five known as the "Philips' Technical Library."

The treatment of television receivers has been emphasized; however, engineering principles involved in the art as a whole have been developed and sufficient detail included on transmitting equipment to aver that the book covers essentially the whole field.

The 13 chapters are: General Review; Physical Principles of Electronic Scanning; Pick-up and Picture Tubes; Transmission and Separation of Information; The Excitation and Application of Electrical Relaxation Phenomena; The Time-Base Generator; Generation of Extra-High Tension for the Picture Tube; Wide-Band Amplifiers; The Transmission Line or Feeder; Aerials; Picture Synthesis; Colour Television; and Television Receivers.

Mathematical treatment of engineering level is included whenever required, providing design equations for the practicing engineer. The rationalized system of Giorgi units is used, conversion tables being provided. As the authors state, the mathematics may be omitted without sensible loss by those who wish to be instructed

wholly through qualitative physical concepts.

Although this is a Continental book considerable data are included on British and American television. The American system is sufficiently treated to satisfy the needs of most Americans. For those who wish to compare the three systems the book is invaluable.

In the final chapter schematic diagrams for receivers, complete with parts lists, are given for negative modulated transmissions (Continental and American) and for positive modulated transmissions (British); also presented are symptoms and cures for reception difficulties by means of image photographs. Although this information is usually found only in service publications in America it is proper to repeat that this book is an engineering text.

Most of the references in the bibliography are written in the English language, largely from American engineering and scientific journals.—*Harry R. Lubcke*, Reg. Patent Agent, 2443 Creston Way, Hollywood 28, Calif.

Association of Cinema Laboratories

ON THE DAY before the opening of the SMPTE Convention in Washington, D.C., in October 1952, Neal Keehn of The Calvin Company invited representatives of several motion-picture laboratories to a dinner party in his suite at the Hotel Statler. The purpose of the dinner and the meeting that followed was, as Mr. Keehn stated, "to give motion-picture laboratory people an opportunity to get to know each other better and to discuss some of their mutual problems." This dinner-meeting was attended by representatives of Byron, Inc.; The Calvin Company; Geo. W. Colburn Laboratory, Inc.; Color Service, Inc.; Du Art Laboratories, Inc.; and McGeary-Smith Laboratories, Inc.

At that meeting it was agreed that free and frank discussion of technical, administrative and managerial problems would be of great benefit to those participating and to the motion-picture laboratory industry as a whole. Later, during the week of the SMPTE Convention, a second meeting was held, hosted by Byron Roudabush of Byron, Inc., at which the advantages and disadvantages of forming a formal motion-picture laboratory association were discussed. It was agreed that another meeting should be held, preferably in New York City, at which a considerably larger representation of laboratories would be possible so that a wider base of opinion could be sounded out.

This third meeting, with Du Art Film Laboratories, Inc., as host, could be called the first organizational meeting. Representatives of 16 motion-picture laboratories attended this meeting, and it was voted that a formal trade association would be formed. Plans were formulated to incorporate the association under the laws of the State of New York. Interim officers were elected: John G. Stott, President; Russell Holslag, Treasurer; and Harry B. Sale, Secretary. Annual dues of $50.00 were voted and a tentative program of activity was worked out.

It was hoped that the name of the association could be "The Association of Motion Picture Laboratories, Inc." However, it was learned that a previous association formed years ago had obtained this name and had never been legally dissolved. Hence the name was not available. The officers of the embryo association settled, then, on the present name: "The Association of Cinema Laboratories, Inc." as the next best thing. The association obtained its charter under the laws of the State of New York in March 1953, and a list of bylaws was drawn up.

Subsequent meetings were concerned primarily with organizational details such as approval of the bylaws, appointment of Membership, Admissions, Technical and Executive Committees, and determination of financial, administrative and publicity policies.

At a meeting of the Board of Directors held in July 1953, the first permanent officers of the Association were elected and installed. These officers are:

Neal Keehn	President
John G. Stott	Vice-President
Byron Roudabush . .	Secretary
Geo. W. Colburn . .	Treasurer

The first general meeting of the association under its permanent officers was held November 13, 1953, in Chicago.

The purpose of the Association of Cinema Laboratories, Inc., is to provide a clearing-house and area for debate on various technical and business problems common to all motion-picture laboratories. Some of the typical problems presently being worked on are as follows:

(1) Recommendations for preparation of A and B rolls for 16mm printing.

(2) Recommendations for use of standard head and tail leaders for 16mm printing.

(3) Elimination of notches on 16mm printing films and substitution of an electrical edge-cuing technique.

(4) Preparation of a uniform terminology, nomenclature, list of parts, equipment, films, devices and techniques.

(5) Investigation of means of securing screen credits for processing and printing laboratories.

(6) Establishment of a bureau for the voluntary exchange of technical information.

(7) Providing means of encouraging research on motion-picture laboratory technical problems and of providing a flow of specially trained engineering personnel into the motion-picture laboratory industry by a system of scholarships or fellowships to universities or colleges.

The above items are only those on which positive activity is now in progress. Many other matters are under discussion.

It must be emphasized that the Association of Cinema Laboratories, Inc., does not compete with purely technical societies but tends instead to supplement and implement the activities of those societies. Technical recommendations or standards set up, say by the SMPTE, may be more readily adopted through the devices of the Association of Cinema Laboratories, Inc. Our activities also embrace matters beyond the province of purely technical societies.

One of the greatest benefits of the Association is the opportunity it provides for personal contact between competitors in an atmosphere of friendly and open debate. The Association, chartered under expert legal supervision, forbids discussions of prices or pricing methods. Free interchange of information has brought out that facilities exist in one laboratory that do not exist in another, making it possible to "farm out" jobs with the knowledge that the laboratory to which the job is "farmed" is adequate for the task.

Thus has been our birth and growth in just a little over a year. We're proud that we already have 26 paid-up members. The formation of such an association has been a great task. Plagued by inexperience in such matters, separated as individual laboratories by great distances, struggling with differing problems, methods, needs, requirements and resources, we have our hands full. Our problem now is to communicate effectively with those members who have not so far benefited by attending the 1953 meetings. Our progress probably will be slow, and we'll need all the help we can get. But the rewards are great and we look forward with enthusiasm and confidence to expanding membership and activity.—*John G. Stott*, Vice-President, The Association of Cinema Laboratories, Inc., 1226 Wisconsin Ave., Washington, D.C.

New Members

The following members have been added to the Society's rolls since those last published. The designations of grades are the same as those used in the 1952 MEMBERSHIP DIRECTORY.

Honorary (H) Fellow (F) Active (M) Associate (A) Student (S)

Boyle, Charles P., Cameraman, Director of Photography, Universal Studios. **Mail:** 12628 Otsego St., North Hollywood, Calif. (M)

Carlson, Kenneth, Television Film Producer, Larchmont Studios. **Mail:** 1212 North Normandie, Hollywood 29, Calif. (A)

Cramer, Mert, Student, University of California at Los Angeles. **Mail:** 2341 Hillhurst Ave., Los Angeles 27, Calif. (A)

Dolotta, T. A., Drinker 104, Lehigh University, Bethlehem, Pa. (S)

Dowson, Philip Hugh Bourne, Company Director and Chief Engineer, H. A. O'Connor & Co., Ltd., Laidlaw Building, P.O. Box 252, Singapore, Malaya. (A)

Eaton, Richard Edwin, Physicist, U.S. Government — WPAFB. **Mail:** 5693 Gross Dr., Dayton, Ohio. (M)

Edwards, Thomas A., Designer, Engineering and Manufacturing. **Mail:** 10213 Pescadero Ave., South Gate, Calif. (M)

Fleming, Malcolm L., Indiana University. **Mail:** Hoosier Courts 23-7, Bloomington, Ind. (S)

Fournier, Rudolphe, TV Technical Maintenance Supervisor, Canadian Broadcasting Corp. **Mail:** 826 Riverview Ave., Verdun, Quebec, Canada. (A)

Foxe, Morton, Staff Engineer, General Precision Laboratories. **Mail:** 796 Bronx River Rd., Bronxville, N.Y. (A)

Garver, Ray, Chief Engineer, in charge of design, Garver Electric Co. **Mail:** 617 North Columbia St., Union City, Ind. (A)

Gerrie, Alfred L., Jr., California State Polytechnic College. **Mail:** 1118 North El Molino Ave., Pasadena 6, Calif. (S)

Gerstner, John E., U.S.A.F. Quality Control Representative, U.S. Air Force. **Mail:** 86-27 — 85 St., Woodhaven 21, N.Y. (A)

Gottling, James G., Lehigh University. **Mail:** 458 Center St., Bethlehem, Pa. (S)

Gross, C. Robert, Engineer, Columbia Broadcasting System. **Mail:** 8439 Tunney Ave., Northridge, Calif. (A)

Hinerman, Millard T., Motion-Picture Printing and Processing-Equipment Mechanic, U.S. Naval Photographic Center. **Mail:** 3339 Buchanan St., #301, Mt. Rainier, Md. (A)

Huot, Louis, Producer, Huot Productions, Inc. **Mail:** 2875 Glendale Blvd., Los Angeles 39, Calif. (M)

Killian, Kenneth K., Manufacturer's Representative. **Mail:** Box 364, Hempstead, N.Y. (A)

Laidlaw, Ron, Film and Photographic Director, CFPL-TV, London Free Press Printing Co., Ltd., Richmond St., London, Ontario, Canada. (A)

Lambert, Sam, Unit Manager and Assistant Director, Magna Theatre Corp. **Mail:** 200 W. 54 St., New York, N.Y. (A)

Leslie, Edward S., Model Maker, RCA Victor Div., Radio Corporation of America, 1560 North Vine, Hollywood, Calif. (A)

Luce, Ralph W., Motion-Picture Producer, Pearson & Luce Productions, 505 Geary St., San Francisco, Calif. (M)

Martinez, Rene C., Illuminating Consultant, Otto K. Olesen Illuminating Co. **Mail:** 9012 Crescent Dr., Hollywood 46, Calif. (M)

McCubbin, John G., Mechanical Engineer, RCA Victor Div., Radio Corporation of America. **Mail:** 2912 Washington St., Camden 5, N.J. (A)

McDonald, Duncan Hamilton, Branch Manager, General Theatre Supply Co. **Mail:** 266 Waterloo St., St. John, N.B., Canada. (A)

McGreal, E. B., Head, Film Operations, Young & Rubicam. **Mail:** 8423 Fountain Ave., Los Angeles 46, Calif. (A)

McNamara, Daniel N., Television Engineer, Columbia Broadcasting System. **Mail:** 17353 Hatteros St., Encino, Calif. (A)

Milner, Irving, Chief Projectionist, Skouras Theatres Corp. **Mail:** 221-12 — 69 Ave., Bayside 64, N.Y. (M)

More, Harry, Manager, Westrex Co. (Asia), 304 Victory House, Hong Kong. (M)

Mueller, George J., Engineer-Physicist Consultant, Douglas Aircraft Co. **Mail:** 456 North Bowling Green Way, Los Angeles 49, Calif. (M)

Newman, James J., Executive Head, Coast Film Service. **Mail:** 3611-31st St., San Diego 4, Calif. (M)

Palmieri, Victor A., Television Engineer, KLAC-TV. **Mail:** 521 La Paz Dr., Pasadena 10, Calif. (A)

Parrish, Fred A., Motion-Picture Cameraman. **Mail:** 10851 Fairbanks Way, Culver City, Calif. (A)

Phillips, Alex, Motion-Picture Cameraman, Heriberto Frias, 948 Col. del Valleiz, Mexico, D.F. (A)

Picker, Eugene, Theatre Executive, Loew's, Inc., 1540 Broadway, New York, N.Y. (A)

Plambech, Albert O., President and Technical Director, Horn Jefferys & Co. **Mail:** 4757 Anola Ave., North Hollywood, Calif. (M)

Randolph, Dorthia, Research Technician, Melpar, Inc. **Mail:** 5662 Eighth Rd., North, Arlington, Va. (A)

Rankin, John A., Vice-President, Director of Engineering, The Magnavox Co., Fort Wayne 4, Ind. (M)

Raskin, L. J., TV Engineer, Kinescope Recording, National Broadcasting Co. **Mail:** 11016 Califa St., North Hollywood, Calif. (A)

Rippe, Herbert Louis, Assistant Project Engineer, U.S. Government — WPAFB. **Mail:** Thomas Trailer Court, Fairborn, Ohio. (M)

Rosenthal, Murray, Cameraman and Service. **Mail:** 2601 Tenth Ave., South, Birmingham, Ala. (A)

Row Kavi, Sadashiv J., Motion-Picture Producer and Distributor, Chitra Sahakar (Production Unit), 2 C & D, "Naaz," Lamington Rd., Bombay 4, India. (M)

Schaefer, Fred J., Sound and Projection Engineer, European Motion-Picture Service, U.S. Army. **Mail:** Robinson Barracks Apts., 6B-3, Stuttgart, Bad Canstatt, Germany. (M)

Shono, Nobuo, Chief Engineer, Fuji Photo Film Co., Minamiashigaracho, Kanagawaken, Japan. (A)

Solomon, Robert, Industrial Engineer, U.S. Naval Supply Research & Development Facility. **Mail:** 200 E. 16 St., New York 3, N.Y. (A)

Stark, Milton, Motion-Picture Producer, Stark-Films, 537 North Howard St., Baltimore 1, Md. (M)

Stensvold, O. C. Alan, Cinematographer. **Mail:** 3724 Muirfield Rd., Los Angeles 16, Calif. (M)

Thomas, Dolph, Business Representative, International Sound Technicians, Local 695, 7614 Sunset Blvd., Hollywood 46, Calif. (M)

Thomas, Donn H., Public Relations Director, Pacific Union Conference of Seventh-Day Adventists, 1545 North Verdugo Rd., Glendale, Calif. (M)

Thomas, William H., Executive, James B. Lansing Sound, Inc., 2439 Fletcher Dr., Los Angeles 39, Calif. (M)

Vandervort, D. L., Physicist, Eastman Kodak Co., Kodak Park, Rochester, N.Y. (A)

Walker, A. Prose, Manager of Engineering, National Association of Radio & Television Broadcasters, 1771 N St., N.W., Washington 6, D.C. (M)

Warren, Aubrey C., Manufacturer, 10633 Chandler Blvd., North Hollywood, Calif. (M)

Weller, William R., Photographic Engineer, Eastman Kodak Co. **Mail:** 381 Meadow Dr., Rochester 18, N.Y. (A)

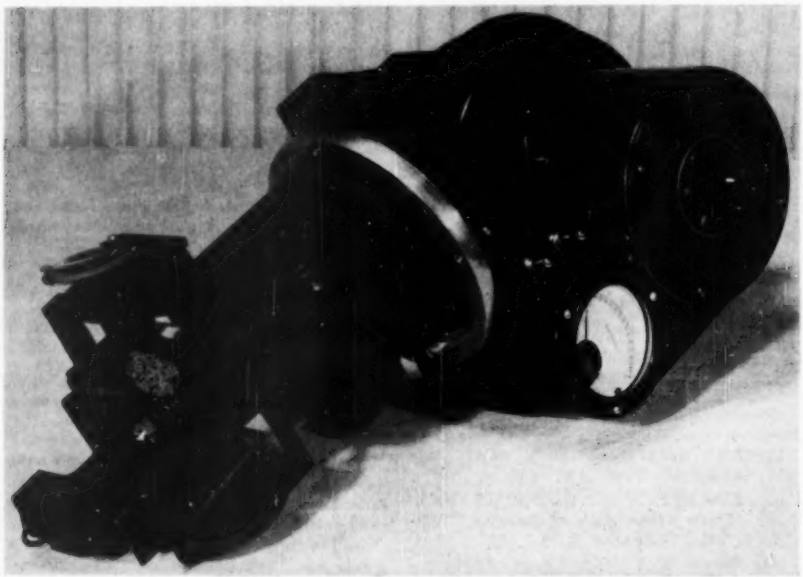
Williams, Howdy L., Cameraman. **Mail:** 8021 Radford Ave., North Hollywood, Calif. (M)

DECEASED

Weisser, Frank E., President, Color Laboratories, Inc., P.O. Box 637, Islip, N.Y. (M)

New Products

Further information about these items can be obtained direct from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of these items does not constitute endorsement of the products.



A new 300-w intensity light source has been offered by Bell & Howell, to produce up to 215 ft-c at the printing aperture. In addition to the greatly increased light output, the new unit has improved uniformity in density across the printing aper-

ture, a dowser shutter permitting preheating to desired color temperature, a new design for cooling the lamp and filters, new heat-absorbing glass, a printing lamp with a 200-hr life, a suppressed scale-type ammeter and a rheostat for greater exposure range. The price is $595.

Involving no major physical changes in existing equipment, this unit will be available as standard equipment on all new 16mm and 35mm Bell & Howell printers manufactured after the first of this year. Installation of the unit on printers now in the field can be readily accomplished without returning the printer to the factory.

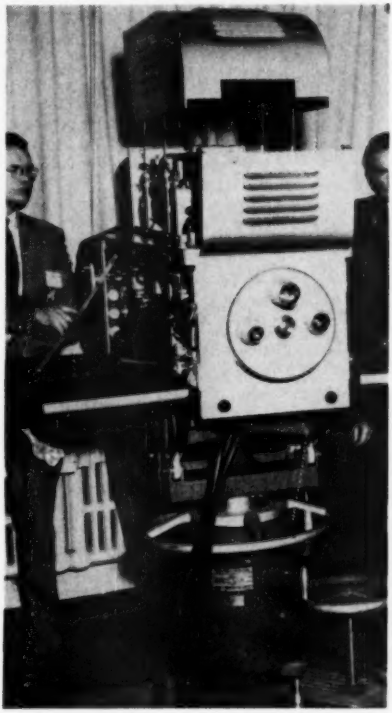
Design uses a 300-w, 120-v base-up lamp with a 200-hr life. The light intensity is controlled by a 35-ohm rheostat from 1.8 to 2.66 amp shown on the ammeter of the suppressed-scale type which makes possible a closer reading of light intensity. A small additional reflector alongside the main spherical filament reflector furnishes light for the edge printing.

Automatic cooling is provided for the lamp, filters and rheostat. The gelatin color filters are further protected by a heat-absorbing glass filter. By a special switching arrangement, the cooling fan will continue to operate after the lamp is shut off, thus preventing a heat build-up at the gelatin filters.

The optical system has one cylindrical and two spherical condensers. A prism is used to bend the rays. The coated optical elements increase the light intensity to more than 10 times over the nonoptical attachment. The addition of a cylindrical condenser elongates the light spot at the aperture, giving uniform light intensity across the aperature for both 16mm and 35mm film sizes.

A ring-type spacer is used on top of the lamphouse for aligning the prism and second condenser. Realigning is not required after the original adjustment is made. Two screws tighten the ring to the lamphouse.

For normal exposure at 60 fpm using Eastman fine-grain, release positive film with a 1.5 neutral density filter, the ammeter reading is set to 1.8 amp and the shutter to stop # 8. The exposure for color printing will depend on the color filters used, in addition to lamp current and shutter stop. For checking exposure correctly, a densichron meter with a special Bell & Howell attachment should be used. The range in foot-candles without neutral density filter is 35 to 415 with # 22 stop.



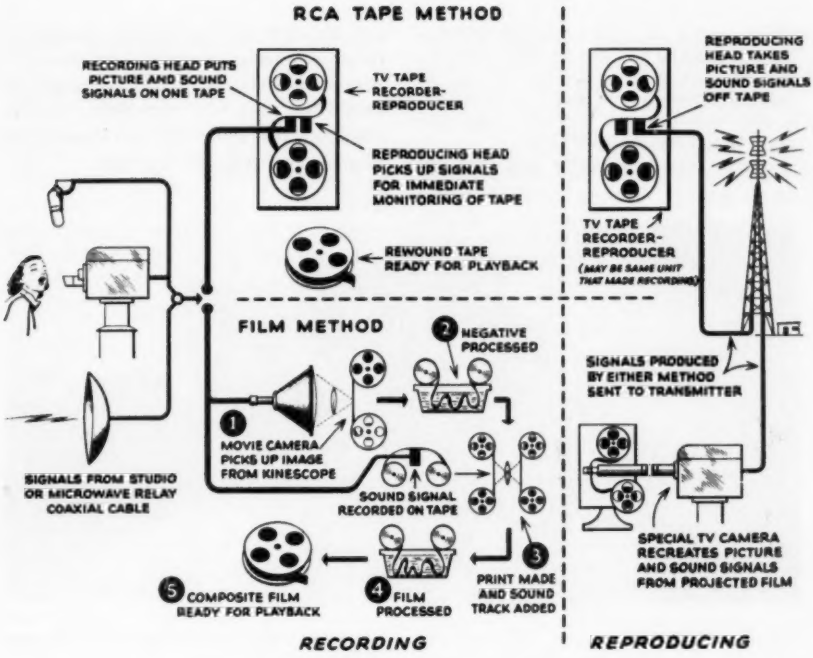
RCA's new Color TV Camera was demonstrated in October at Camden to a clinic of broadcast consulting engineers. RCA has announced that it will start delivering color telecasting equipment before the end of 1953. The first equipment, consisting of color monitors and terminal apparatus to be added to existing television transmission facilities, is designed to enable stations to telecast programs received over telephone circuits. Other equipment is planned for next year for transmitting in color from slides, film and live studio productions. The equipment now being produced is on a custom basis, for the standards approved by the FCC may be such that some modification will be required in commercial production to come later.

Video recording on magnetic tape was demonstrated for the first time by RCA on December 1, 1953. A color television program originating in NBC studios in Radio City, New York, was beamed by microwave to the David Sarnoff Research Center at Princeton, N.J., and there simultaneously shown and recorded on magnetic tape. During part of this transmission, both the live program from the microwave radio relay and an immediate playback of the magnetic tape recording were shown on two separate receivers. As soon as the tape reel was rewound, it was played back and the recorded television pictures appeared on the two color television receivers. Black-and-white reproduction was also demonstrated.

The principle of video recording resembles that of sound recording. Since video signal frequencies range up to 4 mc, however, special recording and reproducing heads had to be developed in order to bring tape speed within manageable limits. In the equipment demonstrated tape speed was 30 fps, and recording was said to reach 3 mc.

Reels used with the demonstration equipment were 17-in., capable of recording 4 min of a television program. RCA is working now for a 19-in. reel which will carry a 15-min program.

Special recording and reproducing amplifiers have been designed to take into account and compensate for the characteristics of the heads and magnetic tape ma-


RCA TAPE METHOD
RECORDING HEAD PUTS PICTURE AND SOUND SIGNALS ON ONE TAPE
TV TAPE RECORDER-REPRODUCER
REPRODUCING HEAD PICKS UP SIGNALS FOR IMMEDIATE MONITORING OF TAPE
REWOUND TAPE READY FOR PLAYBACK
REPRODUCING HEAD TAKES PICTURE AND SOUND SIGNALS OFF TAPE
TV TAPE RECORDER-REPRODUCER
(MAY BE SAME UNIT THAT MADE RECORDING)
FILM METHOD
2 NEGATIVE PROCESSED
SIGNALS PRODUCED BY EITHER METHOD SENT TO TRANSMITTER
1 MOVIE CAMERA PICKS UP IMAGE FROM KINESCOPE
SIGNALS FROM STUDIO OR MICROWAVE RELAY COAXIAL CABLE
SOUND SIGNAL RECORDED ON TAPE
SPECIAL TV CAMERA RECREATES PICTURE AND SOUND SIGNALS FROM PROJECTED FILM
3 PRINT MADE AND SOUND TRACK ADDED
5 COMPOSITE FILM READY FOR PLAYBACK
4 FILM PROCESSED
RECORDING
REPRODUCING

terials in recording the wide bands of frequencies used in television.

Since even small variations in the speed of the tape and the pressure on the head can create noticeable effects on the picture, it was necessary to devise precision apparatus to control accurately the speed of the tape at the recording and reproducing points. Greater precision in regulating speed and pressure is the object of research which RCA has under way.

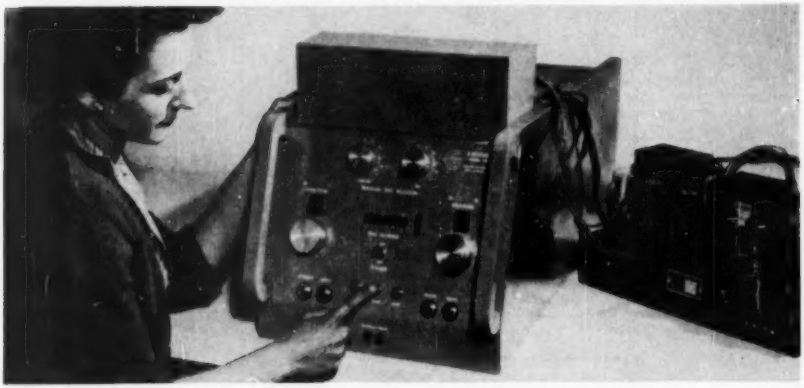
For video tape recording of color television with the RCA system, five parallel channels are recorded on ½-in. tape. There is one recorded channel for each of the primary color signals (red, green and blue), for the synchronizing signal, and for the sound signal. For black-and-white recording the ¼-in. tape carries two recorded channels, one to carry the video signal and the synchronizing signal, and one for the sound signal.

To rebroadcast a color television program from a tape recording it would be necessary to combine the three primary color signals with the synchronizing signal to form a composite signal to send to the transmitter. While this operation is not yet ready for demonstration, RCA says that it is the subject of current development.

RCA has released comparative estimates of operating costs which are highly favorable to tape as opposed to film recording. Although magnetic tape today costs more per minute of program time than 35mm color film, the fact that tape needs no processing before playback compensates for the expense of raw tape. Recording black-and-white programs on film is estimated by RCA engineers to be at least five times as costly as it would be on ¼-in. magnetic tape, assuming that the tape would be reused many times. In making copies for distribution to television stations, they say, a half-hour program could be taped for less than $15 per copy, provided the tape is reused. Even greater economies are estimated for making the original tape recording of color television programs,

which under normal operating circumstances could be handled for only 5% of the cost entailed in color film recording. In making copies on tape that is to be reused, a tape recording of a half-hour color program would cost roughly $20.

Despite the very visible line structure and the slight washout of color, viewers at the demonstration appeared to be agreeably impressed with the accomplishments in developing this new technique. RCA's estimate is that equipment will be available commercially in about two years.



The new CTI Supertester, manufactured by Color Television Inc., 994 San Carlos Ave., San Carlos, Calif., permits testing of electronic or electrical products at the rate of several checks per second. As many as 400 individual automatic sequenced tests can be made.

The tests themselves can be distributed as required among the following six basic types: continuity, leakage, d-c voltage, a-c voltage, resistance and impedance. In addition, derivative characteristics such as gain, frequency response, phase relationships and noise levels are determined automatically through the combination of two or more of the standard tests. Circuitry is included to allow manual dialing to any one of the tests. Accessory signal generators, dropping resistors, etc., can be used with this tester to permit tests at frequencies or voltages outside its normal scope.

The master cabinet contains the basic switching units and electronic measuring circuits. No internal changes or adjustments are required for any test sequence. Adapters, which are plugged into the top of the master cabinet, are individually laid out and wired to meet the requirements of each particular type of production equipment under test.

In operation, the attendant attaches the adapter leads to the equipment to be tested and presses the starter button. The instrument proceeds through the sequence of tests, sounding an alarm on the discovery of a fault, on reaching a test which requires an adjustment to the product, and on reaching the end of the entire sequence. The adjustment step can be made on a go/no-go basis with the attendant not being required to measure or even understand the particular adjustment.

A new version of the Photovolt Densitometer, including new accessories, is announced in a new bulletin by Photovolt Corp., 95 Madison Ave., New York 16, N. Y. Following indications by R. C. Lovick of Eastman Kodak Co. in his paper "Densitometry of Silver-Sulfide Sound Tracks," published in the August 1952 *Journal*, a special search head is now supplied which permits measurement of infrared density of silver-sulfide sound tracks. The head contains a phototube with S-1 response.

The Neuscope splicer, specially developed for use with CinemaScope film, has been announced by Neumade Products Corp., 330 W. 42 St., New York 36. Although the new splicer resembles the conventional Griswold splicer in appearance it has the smaller-sized pins, differently located, necessitated by the smaller sprocket holes of CinemaScope film.

It has also been found that the way to get a perfect splice in true alignment was by keeping the film locked in one position throughout the splicing operation. Splicing procedure on CinemaScope film has until now meant removing the film from the jaws in the middle of the splice, turning it over, scraping the soundtracks from the back and replacing it in its original position before applying the cement. The Neuscope splicer enables the user to scrape the emulsion from the top of the film in the conventional manner and then remove the soundtracks from the back of the overlap without taking the film out and turning it over — it is locked in its original position throughout the entire splicing operation.

Employment Service

These notices are published for the service of the membership and the field. They are inserted for three months, at no charge to the member. The Society's address cannot be used for replies.

Positions Wanted

Motion-Picture Television Technician: 10 yr intensive skill and know-how related to 16-35mm cinematography, animation, recording (optical, tape, disk), editing, laboratory processing practice (black-and-white, color); also kinescope recording techniques; self-reliant; inventive; relocate if required; write: CMC, Technical Associates, 60 East 42d St., New York 17, N.Y.

Motion-Picture Cameraman: Retiring from Naval Service. 15 yr experience in camera operation, printing, processing, adm. and supervision of production crews. Desires position in TV, educational or industrial field, inaugurating a motion-picture program. Available after May 1954. Prefer West Coast. Write: W. W. Collier, 422 W. Jackson Ave., Warrington, Fla.

Positions Available

Wanted: Sound Engineer for New York film production studio, operation and maintenance on optical and magnetic sound equipment; electronics background essential. Send résumé to R. Sherman, 858 West End Ave., New York, N.Y.

Technical Photographer, age 27 to 38, for senior position with large California industrial research organization. Should be conversant with contemporary techniques for recording data; acquainted with microscopy, graphic arts and color processes. Job involves application of photographic techniques as experimental tool in research projects. Administrative experience helpful. Excellent career opportunity for an ingenious and inventive person. Retirement pension and other benefit plans. Application held in strict confidence. Write giving personal data, education and experience to Henry Helbig and Associates, Placement Consultants, Examiner Bldg., 3d and Market Sts., San Francisco 3, Calif.

Sound Engineer: Complete responsibility for sound control, including printing, processing, maintenance of standards, etc. Tri Art Color Corp., 245 West 55th St., New York 19, N.Y.

Motion-Picture Supervisor, GS-8: Duties as Chief of Motion Picture Section to include all phases of aeromedical research cinematography. Experience in planning, directing, lighting, color control, recording in single or double-system sound. Laboratory work requires experience with sensitometric control equipment, contact printers, automatic processors, Moviola, sound synchronization equipment, titlers, etc. For detailed information write: Photography Officer, USAF School of Aviation Medicine, Randolph Field, Texas.

Motion-Picture Sound Transmission Installer and Repairer, for the Signal Corps Pictorial Center, Long Island City, N.Y.—one at $2.59/hr; one at $2.29/hr (40-hr week). Applicants for $2.29/hr position must have had 4½ yr progressively responsible experience in the construction, installation and maintenance of electronic equipment, of which at least 1½ yr must have been in the specialized field of motion-picture film, disk or magnetic sound recording or reproducing equipment. Applicants for $2.59/hr position must have had at least 5 yr responsible experience in the design, development and installation of electronic equipment, of which at least 2 yr must have been in the specialized field of motion-

picture film, disk or magnetic sound recording or reproducing equipment. Must be familiar with filter design and transmission testing, involving the use of a wide variety of testing and measuring devices. Each year of study successfully completed in a residence school above high school level in electrical, electronic or radio engineering, may be substituted for the general, but not the specialized experience indicated above, at the rate of one scholastic year for each 9 mo. of experience. All applicants must be familiar with Western Electric and RCA systems. Obtain Form SF 57 at any first class Post Office or Government Agency; forward or bring completed form to Civilian Personnel Division, Signal Corps Pictorial Center, 35–11 35th Ave., Long Island City, N.Y.

Photographic Engineer: Wanted for design and development work involving application of film and associated equipment to monochrome and color TV systems. Prerequisites are BS or equivalent, and experience in at least one of the following motion-picture fields: (a) TV film applications, (b) processing laboratory design and operation, (c) camera and projector design or (d) sensitometry and densitometry. Please send résumé to Personnel Dept., CBS Television, 485 Madison Ave., New York 22, N.Y.

Sales Management Engineer: To head division manufacturing single optical track stereo sound system. Already adopted by major studio. Position requires knowledge of theater sound systems here and abroad. Reply to: Fairchild, Rm. 4628, 30 Rockefeller Plaza, New York 20, N.Y.

Engineer: To direct engineering of flying-spot TV projector with millisecond pulldown mechanism. Mechanism already developed and working. Reply to: Fairchild, Rm. 4628, 30 Rockefeller Plaza, New York 20, N.Y.

Wanted — Consultant technician: Thorough knowledge of Houston continuous double-head printer, Houston developing machines, Bell & Howell printers and Debrie Matipo step printer. Must put machines in running order and train operating personnel. Usual per day rate and plane fare to Puerto Rico. Address replies to R. J. Faust, Chief, Cinema Section, Dept. of Education, Commonwealth of Puerto Rico, Division of Community Education, P. O. Box 432, San Juan, Puerto Rico.

Meetings

American Institute of Electrical Engineers, Winter General Meeting, Jan. 18–22, 1954, New York

National Electrical Manufacturers Assn., Mar. 8–11, 1954, Edgewater Beach Hotel, Chicago, Ill.

Radio Engineering Show and I.R.E. National Convention, Mar. 22–25, 1954, Hotel Waldorf Astoria, New York

Optical Society of America, Mar. 25–27, 1954, New York

The Calvin Eighth Annual Workshop, Apr. 12–14, 1954, The Calvin Co., Kansas City, Mo.

Society of Motion Picture and Television Engineers, Central Section, Spring Meeting, Apr. 15, 1954, The Calvin Co, Sound Stage, Kansas City, Mo.

75th Semiannual Convention of the SMPTE, May 3–7, 1954, Hotel Statler, Washington

American Institute of Electrical Engineers, Summer General Meeting, June 21–25, 1954, Los Angeles, Calif.

Acoustical Society of America, June 22–26, 1954, Hotel Statler, New York

Illuminating Engineering Society, National Technical Conference, Sept. 12–16, 1954, Chalfonte-Haddon Hall, Atlantic City, N.J.

Photographic Society of America, Annual Meeting, Oct. 5–9, 1954, Drake Hotel, Chicago, Ill.

American Institute of Electrical Engineers, Fall General Meeting, Oct. 11–15, 1954, Chicago, Ill.

76th Semiannual Convention of the SMPTE, Oct. 18–22, 1954 (next year), Ambassador Hotel, Los Angeles

77th Semiannual Convention of the SMPTE, Apr. 17–22, 1955, Drake Hotel, Chicago

78th Semiannual Convention of the SMPTE, Oct. 3–7, 1955, Lake Placid Club, Essex County, N.Y.

SMPTE Officers and Committees: The roster of Society Officers and the Committee Chairmen and Members were published in the April *Journal*.

Society of Motion Picture and Television Engineers

40 West 40th Street, New York 18, N. Y., Tel. LOngacre 5-0172

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